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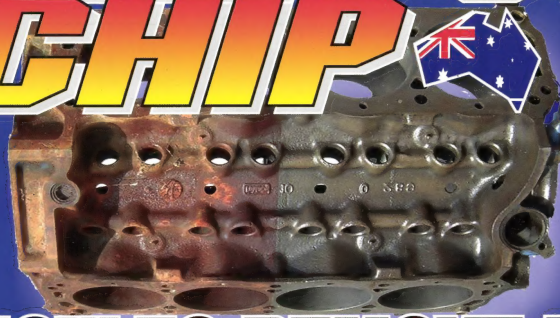

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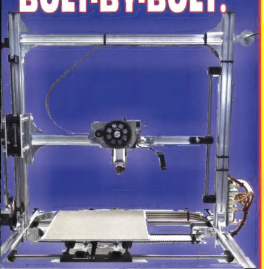


Assembling the new Velleman 3D Printer

PROJECTS TO BUILD:

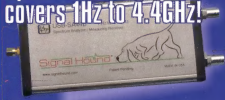
Digital Effects Processor

Passive D-I Box

Courtesy Light Delay

WE REVIEW:

Signal Hound USB Spectrum Analyser covers 1Hz to 4.4GHz!



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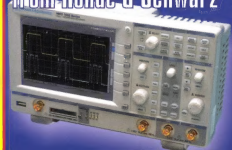

KITS BUILD THEM!

ONLINE & IN STORE

AV & Special Effects Kits

Crazy Cricket and Freaky Frog Kit

Ref: Silicon Chip Magazine June 2012

Designed to imitate the chirping noise of a cricket or gentle croaking of a frog (alternates at power up). It activates in darkness and stops when disturbed by light.

- PCB: 30 x 65mm

KC-5510

$19.95

Kit includes PCB, preprogrammed IC, battery and electronic components.

Jacob's Ladder MK3 Kit

Ref: Silicon Chip Magazine Feb 2013

A spectacular rising ladder of bright and noisy sparks for theatre special effects with even more zing and zap than it's previous design from April 2007. Requires a VS Commodore 12V ignition coil (available separately from auto stores and parts recyclers).

- Powered from a 12V 7Ah SLA (SB-2486 $29.95) or 12V car battery (not included)

KC-5520

$49.95

Kit includes silk-screened PCB, diecast enclosure (111 x 60 x 30mm), pre-programmed PIC, PCB mount components and pre-cut wire/ladder.

IR Remote Extender MKII Kit

Ref: Silicon Chip Magazine October 2006

Operate your DVD player or digital decoder using its remote control from another room. Picks up the signal from the remote control and sends it via a 2-wire cable to an infrared LED located close to the device.

- Requires 9VDC and 2-wire cable for extending the IR-Tx lead (use WB-1702 $0.50/m)
- PCB: 79 x 47mm

KC-5432

$26.95

Kit includes case, screen printed front panel, PCB with overlay and all electronic components.

Theremin Synthesiser MKII Kit

Ref: Silicon Chip Magazine March 2009

Create your own eerie science fiction sound effects by simply moving your hand near the antenna. Features skew control to vary the audio tone from distorted to clean. Easy to set up and build.

- Requires 12V power supply (MP-3147 $17.95)
- PCB: 85 x 145mm

KC-5475

$74.95

Kit includes PCB with overlay, pre-machined case and all specified components.

New Jaycar Kits

Mini-D 2 x 10W Class-D Amplifier Kit

Ref: Silicon Chip Magazine September 2014

Can deliver more than 10W per channel or 30W mono. Features on-board volume control, low-power shutdown mode and over-temperature/current protection. Compact design and highly efficient.

- Powered from 8 - 25VDC
- No heatsink required!
- PCB: 85 x 46mm

KC-5530

NEW!

$49.95

Kit includes double sided, solder-masked and screen-printed PCB, and ALL SMD components pre-soldered to the PCB.

TempMaster Electronic Thermostat MK3 Kit

Ref: Silicon Chip Magazine August 2014

Convert a 240VAC freezer into a fridge, a fridge into a wine cooler or control heaters in home-brew setups, etc. or control 12V or 24V fridges or freezers.

- 12VDC / 150mA
- Immune to relay chatter problems
- Temp range: -23 to 47˚C
- PCB size: 80 x 104mm

KC-5529

NEW!

$39.95

Kit includes short-form with PCB, relay, temp sensor and components. Requires case, sockets and cable to suit your configuration.

Jaycar Electronics

Better, More Technical

Home & Computer Kits

Mains Timer Kit for Fans & Lights

Ref: Silicon Chip Mag August 2012

This simple circuit provides a turn-off delay for a 230VAC light or a fan, such as a bathroom fan set to run for a short period after the switch has been tuned off.

- Consumes no standby power when load is off
- PCB: 60 x 76mm

KC-5512

$39.95

Kit includes PCB, case and electronic components. See website for alternate capacitors to suit.

USB Power Monitor Kit

Ref: Silicon Chip Magazine Dec 2012

Plug this kit inline with a USB device to display the current that is drawn at any given time. Displays current, voltage or power. Auto-ranging and will read as low as a few microamps and up to over an amp.

- PCB: 65 x 36mm

KC-5516

$59.95

Kit includes double sided, solder masked and screen-printed PCB with SMD components pre-soldered, LCD screen, and components. Laptop and USB lead not included.

Automotive & Power Kits

Automatic Headlights Kit

Ref: Silicon Chip Magazine October 2013

Like modern cars, this kit will turn your car headlights on automatically when it gets dark. Features under-voltage cut-out, adjustable light sensitivity and switch-off delay.

- 11.5-15VDC

KC-5524

$59.95

Kit includes double sided, solder-masked and screen-printed PCB, diecast case, buzzer and electronic components. Cabling not included. Some SMD soldering required.

240V 10A Motor Speed Controller Kit

Ref: Silicon Chip Magazine Feb/Mar 2014

An improvement on our successful KC-5478 Motor Controller Kit. Designed for controlling typical brush motor tools such as electric drills, saws and routers. The case has the tricky cut-outs pre-machined, but a little bit of extra drilling is required to complete the project.

- Soft starting
- Over-load/current protection

KC-5526

$149.00

Kit includes machined case, overlay PCB and electronic components.

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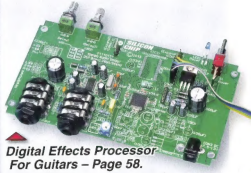

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Publisher's Letter

GPS car navigation still not perfect

Just recently, I purchased a new Sydney street directory and others in the SILICON CHIP office laughed at me. "What do you need that for? You've got GPS and that makes street directories unnecessary". Well, call me conservative but if at all possible I like to know where I am going and I like to know the general route before I get into the car.

Now I think GPS is great. I still boggle at how marvellous it is when, after driving for several hours or maybe even a whole day, the GPS says, "you have arrived at your destination, at such and such address".

But I have also driven up a few byways in other cities before I realised that I was nowhere near my selected destination and unless I had a real map, I was to be stranded somewhere out in "woop woop". Only last month, I had a lunch engagement with one of our regular contributors, Kevin Poulter, at a restaurant in Cloudehill Gardens, in Monbulk, on the outskirts of Melbourne.

I had programmed the address into the GPS on my Garmin Android phone as a matter of routine. The route took me and my wife through the very scenic Dandenongs and as we were driving along a steep, narrow, winding, dirt road, the GPS suddenly said "recalculating". Now as anyone who has used a GPS knows only too well, this is the GPS politely saying "You've just taken the wrong turn-off, you stupid idiot". And since I didn't know the area, I thought that I had done just that.

But after trekking back and forth, going up and down narrow lanes which were dead-ends and becoming more and more angry and frustrated, I had to admit defeat and phone Kevin to tell him we were going to be late – very late! So how did I get out of that one? Fortunately, I had a Melbourne street directory in the car. I was able to retrace the route until I could find a street sign and then I was able to navigate in the old-fashioned way – with a proper map! We arrived an hour late and it took me a while to calm down and enjoy the meal. By the way, I had not taken the wrong turn-off.

It turns out that this experience is not at all uncommon, especially in hilly country areas or built-up city streets and with cloudy conditions whereby the GPS loses reception of the satellites. The waitress at the restaurant had seen all this before – many times.

But it is not just intermittent loss of satellites that can get GPS units into trouble. Even if the stored maps are supposedly up-to-date, who has not been barrelling down a freeway somewhere and then been instructed to take the first exit at the next round-about? And there is no round-about for the next 50km? Or maybe you are in a city area where they have recently made a lot of changes to the roads and you end up driving into a hotel foyer – or at least you would if you had blindly followed the instructions of the GPS. Don't laugh; people do such stupid things and some have died as a result.

You also have to be careful to see that the GPS route selection criteria are correct for your purpose. Do you want the quickest route or the shortest? Do you want to avoid toll-ways? And so on. These can make a dramatic difference to the time (and cost) of your journey. By the way, you can plan your route point-by-point on the GPS instead of merely plugging in the destination address and then putting your faith in its digital machinations.

But there is another reason why I like proper maps. Several years ago I had an evening meeting with a sales representative in a Melbourne restaurant. I arrived on time but he arrived very late and he apologised profusely. I asked him why and he said that he had inadvertently left his Tom-Tom GPS in his other car – he could not find his way without getting repeatedly lost. And he had been a Melbourne resident for several years! I laughed but I wonder how many people these days would also be lost and unable to proceed without a GPS?

Leo Simpson

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Earth conductivity has always been a problem

The Publisher's Letter and related article on the MEN system, house water pipes and electrical safety brings to mind a situation I experienced back in the mid-1960s as a designer of HMV electronic equipment. This was the time when 'rectification' first became a problem with the 'new' HMV transistor amplifiers, both from noisy appliances and AM broadcast stations. At about the same time, hot water 'ripple tone' switching was introduced, with interference coming from the mains wires as they entered the chassis. This was another unrelated, capacitance-linked problem.

On visiting an affected home, the combined rectified (audio) output from 2CH and 2SM at Carlingford was heard loudly at minimum volume setting, even before the AM tuner was switched on! We later minimised this problem with copious use of input 'base-stopping' resistors (read 'grid-stoppers') and bypassing of external wires, including the shield of shielded wires, as they entered the chassis, with a ceramic capacitor. Admittedly the home I visited was part of a new estate in the shadow of the transmitter tower. The relatively high RF impedance above "real" earth of the mains earth wiring compounded the problem.

A second problem for the householder was that if a neighbour's ELCB (earth leakage circuit breaker) was tripped, theirs would also. On returning from a week-end away, the householder would be greeted with a 'dead' fridge full of bad food.

I immediately contacted the local electricity retailer who resolved the tripping problem. Fifty years may have 'seniored' my memory, however I believe the tripping problem was caused by relatively high soil resistivity in that locality. After that, I suspect that the electricity retailer may have inserted deeper Earth stakes at each home for better earth conductivity.

With apologies to Sunbeam, concerning the 'rectification' problem, when developing new amplifiers, my favourite noise generator when testing a prototype was a Sunbeam Shavemaster!

Also at that time, Club electronic lighting dimmers first became popular. These dimmers were heard loudly in the amplifiers. PA amplifier and mixer designers had previously designed their units for a perfect world. Again, bypassing the ineffectual "balanced" microphone leads from the outer shield via a ceramic capacitor at external point of entry to the chassis usually cured the problem. This way earth loops were avoided. Anyone who has designed car radios and antenna entry would know about this!

Neville Snow,
Burwood, NSW.

Products purchased on-line can be unsafe

Further to your article on electrical safety last month, I have encountered an issue which you might like to make more widely known. A friend of mine purchased thirteen 10W and 20W LED floodlights from an internet supplier for use in stage lighting for musical events. The lights are similar in outward appearance to the ones supplied by Oatley Electronics and featured in separate articles in February and November 2012 issues of SILICON CHIP.

The lights my friend purchased were manufactured in China. The casings are metal and the lights are operated from the 230VAC mains via a standard 3-pin plug which is fitted to the lead

Query on MEN fault current

I was most interested to read your article entitled "Your House Water Pipes Could Electrocute You" in the August 2014 issue.

With regard to the panel on on page 19 stating that "currents can flow even when the power is turned off!", where was this measured current actually coming from?

Many years ago I was working on a technical research project and I measured a voltage on the Neutral line. Aghast, I contacted the resident qualified electrician and it was explained that this was quite normal. In relation to the current you measured in paragraph two, which way was it flowing?

I well realise that with an AC system current flows both ways! But consider only one half of the Hertz (cycle) or an even more simplified DC approach. If the supply Neutral has a higher potential than the ground potential, then the current flowing in the water pipe should be identical to that of the Neutral but opposite in direction.

This could be an inherent problem with the M.E.N. system, for the mains Neutral and the property Neutral are tied to the common bar of the property in question and are not disconnected when the main supply (Active) switch is open-circuit.

So, if you could have open-circuited the mains Neutral at the same time as the Active was open-circuited, would the ground (water pipe) current have measured near zero? I believe the answer would be yes.

Ray Smith,
Hoppers Crossing, Vic.

Leo Simpson comments: the current would cease to flow if the Neutral link was disconnected but that would not indicate where the actual fault lay. All that could be certain was that the fault was elsewhere, with one or more of the the neighbours having a Neutral fault.

Query on range of RC substitution box

With respect to the Resistance/Capacitance Substution Box in the August 2014 issue, I am a bit puzzled by the capacitance values you state this box can produce.

On page 77 as an example, the truth table states that when the switch is set to 9, pins 1 and 8 are joined together. Now if you look at the circuit diagram on page 78, pin 1 has a 10µF capacitor and pin 8 has eight 10µF capacitors. These capacitors are all in parallel which to my way of thinking makes 90µF not 9µF. Taking all the other switches into account, this would mean that the total capacitance with all the switches set to 9 would be 99.9999µF not 9.99999µF as you state.

B. Dodding,
via email.

Comment: you are correct.

on each light. A small sealed LED driver is used inside each light to convert the 230VAC mains to LED voltage. One of the lights stopped functioning and my friend asked me to have a look at it. After examining this light I asked him to let me have a look at the other twelve.

Of the 13 lights, only two were properly earthed. The earthing is supposed to be achieved by a tag washer crimped to the Earth wire which is then screwed to the metal body of the light inside the rear cover. I found a variety of faults on the units such as:

- missing tag washers on the earth wire so that earthing is achieved at best via a few strands of copper under the (mostly countersunk) screw head;
- the earthing screw bedded on the plastic insulation of the Earth wire instead of the copper;
- screws used in a blind hole which were too long to tighten against the tag washer so that the earth wire was loose;
- countersink screws used instead of round-head screws which had caused the tag washer to fracture, resulting in only a minimal area of contact against the casing;
- casings screwed down so that screw heads were digging into the mains wiring.

A check with a continuity tester showed only two valid Earth connections. If a fault developed in the LED driver, it would seem to be possible for the casing to become live at 230VAC. There are a number of external unpainted screws, brackets and other items which could easily be contacted by an unsuspecting person. The potential disaster which could have resulted from this situation is unpleasant to contemplate.

These lights have neither an on/off switch nor a fuse and unfortunately there is insufficient space in the casing to fit either one.

I appreciate that policing of safety standards for goods purchased via the internet is all but impossible. Accordingly, it would seem that compliance with the most basic safety standards in inexpensive equipment operated from mains voltage cannot be assumed and users should have such equipment examined by a competent person before operating it.

Barrie Davis,
Hope Valley, SA.

Mailbag: continued

Keyless car entry & flat batteries

Having a passion for cars, I am always interested in car-related service stories whenever they appear in the Serviceman's Log pages. I've always wondered about those cars that only offer a fob and no key as such, as the key and fob are one in the same. Or the key is actually just a remote that is like a credit card or a swipe card in such cars as Mercedes Benz etc.

A lot of much cheaper cars are coming out with this type of key fob which allows smart key entry. The thing that always intrigues me is that you can't just push the button on the fob to get into the car if the battery in the fob is flat for instance. You can't put a key in the door of a Mercedes Benz but a lot of cars with smart key and pushbutton start often have buttons on the doors instead of just a spot to put the key in case of emergency entry if the fob doesn't work.

But if the car has a flat battery you can't even get into the car in that particular case, can you?

Kyle Cogan,
Wangaratta, Vic.

Carbon dioxide emissions from volcanoes deliberately understated

I have read the articles on both sides of the argument of global warming over the last few editions with interest.

However, the letter entitled "Volcanoes not major emitters of carbon dioxide" in the August 2014 edition has prompted me to write in total amazement on the gullibility of some who accept poorly prepared guesswork and estimations wrapped in a sham of authority to be a credible source.

More surprisingly, the opening line criticises John McDonald for "not verifying his facts", which unfortunately and actually is the writer's, of that letter, greatest failing.

The referenced web site (http://volcanoes.usgs.gov/hazards/gas/climate.php) appears to be a biased compilation from the promoters of the climate warming religion. If one actually reads the suggested site volcanoes.usgs.gov and looks up the reference reports (to verify the facts), one cannot but get the feeling that the outcome of low levels of CO_2 emissions from volcanoes has been based on poor estimates and guesses, masquerading as a peer-reviewed report.

Delving deeper into the analysis, it is even clearer that the selection of volcanoes chosen to study and the assumptions made had the result of an outcome skewed to the ultra-low end of CO_2 output.

For instance, eight of the world's 10 most active volcanoes are omitted from Kerrick's study and making the unscientifically based assumption that the net CO_2 output of all the world's submarine volcanoes (those under the oceans) is zero completely makes the report absolutely worthless and totally misleading.

The referenced website bases its findings on a "projected" CO_2 output of 35GtCpa in 2010, based on "global magmatic" carbon dioxide emission yet the IPCC (the bastion of Global Warming exaggerations) attributes only 9.7 GtCpa to anthropogenic CO_2 emissions – see: http://www.ipcc-data.org/sim/gcm_clim/SRES_TAR/ddc_sres_emissions.html

However, based on the "preferred" and widely used units of measure, this coverts to 0.071GtCpa or 71MtCpa for anthropogenic emissions. This is a tried and proven way of obfuscating report outcomes by using a parallel unit of measure.

In contrast, Morner & Etiope (2002) published a somewhat more representative estimate of sub-aerial volcanogenic CO_2 output based on a more comprehensive selection and found as a bare minimum that sub-aerial

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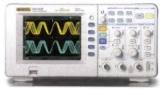

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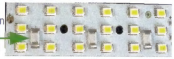

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Mailbag: continued

SILICON CHIP covers a diverse range of topics

While browsing the latest issue of SILICON CHIP magazine and having in mind that magazine's name, I was intrigued by how wide the area of interest has spread and wonder if SILICON CHIP should have a secondary name (a bit like the evolution of R&H, RTV & H, EA etc). The name SILICON CHIP is certainly relevant and has its roots following EA/ETI from the 1960s and the advent of silicon-based semiconductors and ICs.

The Letters pages and reader comments/submissions span automotive topics, volcanic study, medicine, environmental science and atmospherics – along with the evolution of silicon-based (that's broad!) technologies. Heck, one of your major advertisers even sells lathes and metalworking tools!

Engineering in general has remained on a relatively direct path, augmented by the benefits of computing and electronics to optimise and speed up project analysis and delivery. It seems the digital migration of electronics and simulation/augmentation technology has stepped over the line into general engineering and an electronics engineer is rarely a person that builds ham sets or fixes radios any longer. He/she now regularly addresses other real-world problems with colleagues in other disciplines for the present and future.

To this end, perhaps the magazine banner could reflect something like this progress, with a sub-title: SILICON CHIP – Resources for Electronics and Engineering Experimenters or similar.

Michael Coop,
Rowville, Vic.

volcanogenic CO_2 emission is on the order of 163MtCpa. Submarine volcanic output is magnitudes greater than subaerial volcanoes based alone on the significantly greater number (thousands more) and higher level of activity of submarine volcanoes. Together these will diminish the effect of the effective 71MTCpa from anthropogenic sources using the accepted preferred units.

A very interesting and somewhat more credible website covering this area of study and completely debunking the August article and the referenced website is http://carbon-budget.geologist-1011.net/ It is well worth the reading to get the feel of a well-presented and scientific-based document.

Charles Camenzuli,
Seven Hills, NSW.

Electric shock from water taps can be due to other Earth faults

It is with great interest that I read the article about faulty Neutral connections causing electric shocks. However, as an electrician I have been called to two separate incidents where occupants in houses received electric shocks in the shower and their Neutrals were in good order.

In the first case, a person would sometimes receive an electric shock when turning the taps on in the shower while

a dishwasher downstairs was running. I found that the Earth connection was missing on the outlet the dishwasher was plugged into.

In the second case, a person would sometimes receive an electric shock when turning the taps on in the shower. There was a clothes washing machine in the same room as the shower and I found that the outlet the washing machine was plugged into and several others were not earthed. A shock could be received even when the washing machine was not running but just plugged in.

Providing an Earth connection to the outlets that the machines were plugged into fixed the problem in both cases. What I believe was happening is that both of these machines were discharging waste water that had some connection to the Active supply and water with impurities conducts electricity. And both machines' chassis and electrics were not earthed at the time.

As the waste water pipes are plastic, a person walking into the shower and turning on the taps would be quite safe at this point. As the person has a shower, water would run down the shower waste and through the plastic pipes, creating an electrical connection with live discharge water or moist plumbing connections to the non-earthed washing machine. The person having a shower would not be aware that they are standing in a puddle of water which has become electrically live until they touch something else to complete the circuit. When they are finishing their shower and reach out to turn the taps, which are earthed, they will receive a shock.

This is a very difficult problem to diagnose, as it appears to the person having a shower that the taps are live but it is actually the shower floor that was live while the water was running down the floor waste. And of course, the water has dried up in the plastic waste pipe by the time an electrician arrives and his test equipment will show everything is safe in the shower area and the taps are properly earthed.

It is worthwhile plugging in a tester that indicates an Earth connection and can test trip the RCD (safety switch) on outlets that these types of appliances are plugged into regularly, at least once a year.

Donald Whittle,
Phillip Bay, NSW.

Ground stakes must not be surrounded with concrete

I should comment on the photos of the Earth stakes in the Mailbag pages of the September 2014 issue of SILICON CHIP (page 10). While the Earth stake may be correctly wired, it may not have been installed correctly. Nor should it be surrounded with concrete which prevents is from being inspected.

The stake is supposed to maintain effective contact with moist soil that is not subject to excessive drying out.

Guy Reece,
Kelso, Qld.

Sandy coastal areas cause MEN problems

I would like to add a comment to the feature in the August 2014 issue

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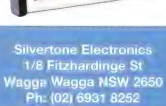

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Mailbag: continued

Plastic pipes & smart water meters

We are a smart meter manufacturer based in Brisbane, Queensland. While primarily electricity metering experts, one of the new products we sell is a plastic smart meter for water. It records 460 days of daily data, has burst, leak, reverse flow and tamper detection and transmits this encrypted data at 923MHz via Wireless M-Bus every 16 seconds for remote reading, all with a 16-year battery life!

The ultrasonic (transient time) meter has no mechanical parts and is completely made of moulded composite material. Obviously this meter would provide a nice "isolator" on any water-pipe earthing system.

In fact, since 1976, you have not been able to use the water pipes as an Earth in new dwellings. It is a requirement to provide equipotential bonding for protection but this is just that, equipotential bonding, not earthing.

At the time many bulletins were issued, like this one at: www.esv.vic.gov.au/Portals/0/Gas%20Professionals/Files/EARTHING%20OF%20ELECTRICAL%20INSTALLATIONS%20USING%20THE%20WATER%20RETICULATION%20SYSTEM.pdf

What you need to remember is that these days most internal plumbing is plastic and now most mains and take-offs to the meter are plastic. Copper is still used above ground for UV resistance, usually just where the meter is installed, where outdoor hose taps are installed and when meters are installed above ground (in Victoria and parts of New South Wales) but poly pipe is installed from the mains to the meter and from the meter to the house.

Only older premises may have the MEN system Earth anchored to the water pipes but as water main replacement is now commonplace, the mains which were providing the majority of the earthing on pre-1976 buildings (usually through the water utilities' large concrete-lined cast iron pipes) are being replaced with non-conductive plastic ones.

For some reason, it seems the water utilities (like Sydney Water) are taking on the responsibility of making sure the premises are cor-

"Your House Water Pipes Could Electrocute You".

The last section on page 19 is of interest as an MEN system can import power system imbalance and problems to the domestic installation. In sandy coastal areas where the main Earth can be a poor or even an intermittent conductor, the MEN system is recognised as a good solution as it connects all Earths together.

However, in sandy coastal holiday areas where the load balance on each phase is unpredictable due to intermittent occupation, considerable Neutral displacement can occur, especially where single phase loading is high, aluminium conductors are used and street earthing is weak, unreliable or corroded and the distance between transformers is considerable.

Where a house is constructed on a concrete slab on the ground, a situation can arise where an uncomfortable voltage may be imported from the power system via a displaced Neutral. The house metal pipes and its main Earth are connected to the substation Neutral via many components.

If there is no connection between the main Earth and the concrete slab reinforcement, the slab will remain floating at local Earth potential. Plumbing fittings can present these two occasionally contrasting voltages, especially in a shower.

A simple but interesting observation can be made by connecting a voltage data logger between a seemingly uninvolved metal fence post remote from your house and your main Earth connection for a day or two. The fence post in this case is the "local natural earth". Any voltage observed is possibly that imported from the unbalanced power system. As long as the 'step and touch' is within acceptable limits, it is not generally noticed.

rectly earthed (using an Earth stake) rather than the Electricity Network Operators and NSW Resources and Energy (who actually do have this responsibility).

How do we, as a supplier of meters, manage our legal risks when the practice of earthing dwellings using the water reticulation system has been outlawed since 1976 when it became mandatory to fit Earth electrodes to all new dwellings?

What is the position where one could argue that a brass meter (or one that has a pathway through it) that conducts electricity could be a hazard because it makes a good electrical path? How do you prove the current rating of a brass water meter or piping system?

By knowingly providing an electrical pathway through the meter, would we breach the rules that impose responsibility for electrical supply networks and associated earthing on NSW Resources and Energy and the Electrical Network Operators (ENOs)?

By knowingly providing an electrical pathway do we compromise the property owner's obligation to ensure the safety of their electrical mains and the earthing system on their property?

This plastic smart meter has no external metal and does not provide any path for AC currents flowing in water pipes.

An interesting article on this topic can be seen at: www.wioa.org.au/conference_papers/08_nsw/documents/johnwerda.pdf

Robert Stewart,
Technical Director,
Smart Building Services Pty Ltd,
Kallangur, Qld.

This characteristic may not be contained to the area fed by your substation only as in many cases the Neutral is usually connected between substations to enhance the MEN effect. It may follow that earth problems in other areas could also be imported to your area. Low-voltage lines running parallel to heavily loaded transmission lines may also induce a problem.

William Fleming,
Launceston, Tas.

Comment on accuracy of Argo measurements

The Argo article by Dr David Maddison in the July 2014 issue of SILICON CHIP was superb and I compliment him on it. However, there was one thing that caught my attention and that was the accuracies that were quoted. In particular, the temperature accuracy seemed too good to be true. Since reading the article, I have searched the internet and found that GEC Instruments sell thermistor temperature measuring units which have an initial accuracy of ±0.002°C (or better) between -10°C and +35°C.

So the accuracy is achievable although there are no deterioration figures. Also, GEC Instruments quote that at 0°C, the resolution of their instruments is 0.0001°C but note that it is resolution, not accuracy.

I know that very high accuracies can be achieved and maintained in laboratories but it requires regular checking and calibration. What is done with the sensors on the Argo drones? There appears to be no further human intervention after the drones are cast adrift. Assuming that the sensors suffer from ageing etc, what is the accuracy after the Argo drones have been operating for some time? The drones are not recovered. How is sensor operation confirmed? I am very curious to

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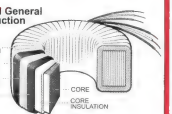

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Mailbag: continued

Non-genuine USB power adaptors are a risk

There's been a lot discussion surrounding the use of non-genuine and non-approved USB power adaptors and rightly so – these things can be dangerous! However, while it's commendable for governments and industry to recommend that consumers look for the Australian approval markings, there is still a hidden danger.

There are quite a large number of adaptors available which are 'copies' of the adaptors supplied by a well-known US phone and tablet manufacturer. I use the term 'copies' very loosely because while these may look like the OEM product in question, inside the case it is a different story, as the following site shows: www.righto.com/2012/10/a-dozen-usb-chargers-in-lab-apple-is.html

The problem arises from the fact that when the copycats reproduce the case, they copy everything – including any safety approval markings that may be present. I myself bought one of the 2-pin US style adaptors some time ago and this is indeed the case – even down to the original manufacturer's inspection mark that's placed on the original article. The copycats do remove the original manufacturer's branding though.

So the average person is going to see the approval markings and think everything is good – which as indicated from the above website, isn't necessarily true! The copycats play to the consumer's taste in that these chargers are quite small and stylish, with seemingly little regard to safety. A quick Google search will reveal this is a worldwide problem, with said famous-name phone manufacturer offering an exchange program in the US in an effort to get these dodgy products off the streets.

The morals – use only genuine parts and/or shop at a reputable place where the markings are genuine. There are good third-party USB adaptors out there, styled along the 'traditional' plugpack style. Sure most of them are black and a little bigger but they *are* safe – at the end of the day it is just a phone charger that sits at home or in a bag most of the time.

Also, if you must use your phone/tablet/MP3 when the battery is flat, why not consider one of the many battery-based 'power banks' now on the market?

Paul Mansell,
Ryde, NSW.

know what was done to maintain the accuracies. It could make for a good sequel to the Argo article.

Also do the researchers prevent aliasing from affecting their results? I know that it seems silly to ask such a question but there are no frequency limits to this effect.

On another subject, a few years ago, I watched a cloud move slowly above Brisbane and then disappear. The water mist had evaporated. The cloud did not change elevation so I assumed that radiant heat was the reason and not a "thermal". Since then, I have realised that there is a possible mechanism by which infrared-absorbing molecules like carbon dioxide or methane could facilitate cloud removal or prevent cloud formation. Since clouds are the major barrier to the expulsion of heat from the Earth, carbon dioxide, methane etc could facilitate some cooling of the Earth.

The physics of the mechanism is as follows. Carbon dioxide molecules absorb low-level infrared radiation and effectively, their temperature is increased. Some of this energy is transferred to surrounding molecules of nitrogen, oxygen and water molecules etc.

If, and I emphasise "if", the water molecules are close to changing state from gas to liquid or liquid to gas, the extra energy will increase the temperature of the water molecules and ensure that they are gaseous. In other words, carbon dioxide and methane etc can reduce existing cloud or reduce the generation of clouds. A reduction in clouds results in more heat being radi-

ated to space and the Earth becoming cooler.

A simple mind experiment suggests that this mechanism is self-stabilising, preventing possible thermal runaway. If the Earth's surface temperature increases, more infrared radiation is produced and more is absorbed by carbon dioxide etc. This would result in less cloud cover and more heat would be released into space. Consequently, the Earth's surface temperature would reduce.

Conversely, a cooling of the Earth's surface temperature would result in more cloud cover but not necessarily a rise in temperature. I have no proof that this mechanism exists but I would be very surprised if it did not. Also, I have no way of gauging its effect on the world's temperature without laboratory experiments and supporting weather data. I will, however, challenge the claim that a rise in carbon or methane levels will ensure a global temperature rise. This mechanism suggests that may not be the case.

George Ramsay,
Holland Park, Qld.

Coupler needed for Ethernet over 3-phase power

I have followed the discussions in SILICON CHIP magazine regarding Ethernet over 3-phase power with great interest. I recalled seeing a device that would enable this to happen and it took me some time to find it again. Jaycar Electronics do sell a unit manufactured by 'Kemo', called a 'Phase Coupler Module' (Jaycar Cat. AA-0268). It needs to be installed by a registered electrician, presumably in the switchboard.

With reference to Peter Lowe's letter in the Mailbag section of the August 2014 issue, I would assume that there is most probably a small copper inductor in the circuit breaker that's part of the magnetic short-circuit trip section of that breaker. This inductor (along with the probably high capacitance of the [presumed] underground cable) may have prevented the HF signals from his brother's Ethernet system from reaching his workshop. Peter didn't say but I hope his brother replaced that circuit breaker with a newer type!

On another topic, I have also read some of the discussions about 'climate change' that many people are making. I have a very good friend who's a recently retired dairy farmer who insists that this 'climate change stuff' is a load of codswallop. I can absolutely swear that something has changed. When I was a young boy in the late 1960s and early 1970s, I would often trot off to school on a frosty morning and walk along the grass berms and crunch through the frost – often in bare feet.

Not only that but any puddles of water would have a layer of ice on top of them too. My Dad also had an old 'copper' out in his garden which was always full of water that he used to wash his feet in. On those hard frosty mornings, I would often be able to pull the 1/2-inch (about 13mm) of glass-like ice off the top and I enjoyed dropping this onto the ground and jumping onto the top of it to break it, or smashing it with a hammer.

He had that copper until it was stolen not that long ago but the ice rarely formed on the top of it any longer. As for climate change, something has definitely changed over the last 45-odd years.

Peter Walsham,
Pukehoe, NZ. SC

New pricing for Celestion drivers

Thanks for the excellent coverage of the Celestion tweeter in the articles on the Majestic loudspeaker system (SILICON CHIP, June & September 2014). However, I should note that there has been a change in our direct pricing and that some constructors may wish to employ the Celestion 15-inch woofer.

The pricing is now: FTR15-4080FD woofer = $339; CDX1-1730 compression driver = $189; T-5134 horn (H1-7050) = $35 (total = $563)

We'll adjust our pricing for October 2014 so that the combined pricing for these three components is $499, as a 'special offer' for SILICON CHIP magazine. This is effectively 2 x $499 for a stereo pair of cabinets.

Mat Bolt, National Sales Manager,
Electric Factory Pty Ltd,
Preston, Vic.
www.elfa.com.au

"Hands On" Product Review. We build the Velleman/Jaycar Electronics

3D PRINTER

If last month's 'Electronex' show is any indication, 3D printers are 'the next big thing' (if they're not already!). Here we take a detailed look at the popular Velleman K8200 3D printer that you first build before you can print. Even one (optional) part of the printer itself can be 3D printed!

3D printers have now featured a few times in SILICON CHIP, some ready-built but some – probably of more interest to the typical SC reader – being for the home constructor.

When a major electronics supplier such as Jaycar decides to stock a kit, you can be sure that they've thoroughly researched the market and decided on an item which will give maximum satisfaction and minimum difficulty.

Team that with the European quality of the well-known Velleman company from Belgium and we're off to a flying start!

Not for the faint hearted!

First, a warning: This kit is not for Dad and Uncle Bert to throw together on Christmas Eve for young Billy to play with the next day.

The kit calls for a substantial expenditure of time and although there are detailed and on the whole accurate and unambiguous instructions, mechanical and electronic skill as well as the ability to download and run a range of software are required.

These skills include a small amount of surface mount soldering, so all-in-all this is not a kit for the beginner.

Having said that, the instructions are extraordinarily detailed and accompanied by numerous photographs — in fact just the build phase is covered by over 850 photographs in 20 chapters, and that does not include testing and setting up!

A clear space

There are two environmental things you will need if you are to successfully build this kit: plenty of workbench space and a completely clean (read spotless!) floor, preferably with a plain surface (ie, definitely not a shag-pile carpet!).

You will drop at least one part of this kit on the floor during construction and that will probably be one of the tiny grub screws in the kit (OK, I speak from experience!).

If the floor does not start off immaculate, you will never find that part.

Now back to space. As you will find, the kit instructions frequently direct you to 'take the bag labelled *n* out of the box'. The box contains 41 numbered bags and one or two that are not numbered, so finding bag *n* will not be a trivial task, especially when you start the build.

You are also frequently directed to use a particular plastic piece, which you can find '...in the bag containing plastic parts'. This bag is crammed with all manner of strangely shaped components, which at first sight look quite different to those in the instructions, especially if you have them a different way up!

The solution to both of these problems is to have enough space to lay out all of the bags of parts and all of the plastic components.

This is in addition to the space in which to build the machine. For this last purpose I built a mobile trolley so that I could move the machine around as construction progressed and get easy access to any part of it.

Most components are clearly numbered to make assembly easy – but some are not, just to make life interesting!

Finally, with regard to the work environment, the work area should also have internet access, in my case a laptop machine.

For a long time now, nearly all suppliers have dispensed with those glossy instruction books that were such a pleasure to curl up with on the sofa or in bed. It is cheaper to supply a CD or DVD.

If the user wants a hard

The completed Velleman K8200 3D Printer from Jaycar. Putting it together is not something you'll achieve in one evening (or perhaps even one weekend!). However, the instructions are very good – just don't assume anything. . .

copy it has to be printed at home.

On-line instructions

This kit takes this a stage further: The 3D printer kit instructions are on-line at www.k8200.eu/locale/

On-line instructions are an advantage to the user as well as the suppliers because they can be amended or corrected as necessary and the changes will take immediate effect worldwide. In fact, some of my suggestions and comments may well have been taken into account by the time you start building your own machine.

First up we have 'Start Building' at www.k8200.eu/manual/building where there are 20 chapters starting with Chapter 0, 'Tools Required' and ending at Chapter 19, 'Assembling the Hot End'.

These chapters can be downloaded as PDF files individually but I found it easier to work directly on-line; plus, there may be cases where the PDF has not been updated to synchronise with the on-line version.

This happened to me when I downloaded the very last chapter — which turned out to be not up-to-date!

My kit was supplied with a new pattern of extruder head ('hot end') thermistor which called for a different assembly procedure.

Although the website had special instructions for this, the PDF had not been updated. Velleman are aware of this via the forum (more later) and this may have been updated since.

The tools you need

The instructions start with an illustrated list of tools. Most of them are tools that any electronics person will already have: a screwdriver, wire cutters/strippers, a multimeter, soldering iron and solder and plastic tuning needle set.

In relation to this last item, what is needed is not your normal IF core tweaker but a really tiny, plastic cross-point tuning/adjustment tool, for adjusting the motor control potentiometers on the controller board as part of the setting up procedure.

Also required are some mechanical tools: a small file set, steel tape measure, digital callipers, metric Allen keys, a set of metric open-end spanners (you will need up to 13mm) and another vital item – circlip pliers.

Circlip pliers

This tool, essential on several occasions during the

build, is variously described as 'combination snap ring pliers' or 'classic circlip pliers for outer rings (shafts)'. It is used to tension (hold apart) a circlip while easing it into a matching groove on the exterior of a shaft (or in this case a linear bearing).

You may have never heard of or tried to use such a tool. It is tempting to try opening a circlip with ordinary pliers. From one who admits to once trying this years ago in desperation on a Sunday afternoon when all relevant shops were shut, in one word — DON'T!

You will not succeed and you could either break the circlip, lose it altogether as it springs away violently, or badly damage an eye; possibly all three! In use, the correct tool engages in holes at the ends of the circlip and enables it to be opened enough to slip onto the shaft or bearing without risking breakage, blinding or other disasters.

As well as the tools recommended, there are one or two omissions in the list. You will find a hot air blower (eg, a hair dryer) essential for heat shrinking the various sleeves to be placed over wire joints.

If you wish to make sure you tighten the extruder nozzle correctly as recommended, you will also need a torque wrench that reads down to 3.5 Newton-metres as well as a matching 13mm socket. Also, I found it useful to have at hand a 30cm steel rule, scissors (for the bags) and small spirit level. Finally, you will need a small vice and (unless you have superb eyesight) a maggy lamp for the surface mount work. I also found a miniature high-speed handheld grinder set useful on one occasion.

Before leaving the tools, I should also mention the soldering iron. The instructions specify 'ceramic soldering iron 30W'. Don't worry about 'ceramic' but the iron should have a very fine point (for the one excursion to surface mount work) and sufficient capacity to quickly solder various connectors and wires, so a 25/30W instrument is best.

As for supplies, everything is in the kit except for solder - and it is also advisable to obtain some isopropyl alcohol from the chemist for cleaning the print bed later.

At last – opening the box!

With everything prepared and all tools at the ready, at last I opened the box, to reveal a very large assortment of parts, mostly in plastic bags labelled with numbers.

The reason for the heavy weight of the box quickly became apparent. Although the frame for this printer consists of cleverly designed extruded aluminium alloy members with various aluminium plates, a major item is the four heavy stepper motors which are the heart of the machine. The main moving parts of the machine centre around heavy stainless steel shafts.

It's helpful to lay out the plastic mouldings.

3D printing – a refresher

We've covered the operating principles of 3D printers before but for the newcomer I'll briefly revise. The purpose of a 3D printer is to fabricate some solid object which can be any shape provided it fits into the available work-space and can be any material within the capabilities of the machine. For a home printer this is invariably a form of plastic such as PLA (PolyLactic Acid).

Traditional fabricating methods are subtractive. That is, we start off with a piece of material, be it plastic, metal or as required. We then machine off chunks (typically on a lathe, mill or drill) and finish up with the shape we require plus a pile of shavings/filings (which in some cases can be recycled).

By contrast, 3D printing is an additive process. For the typical home 3D printer, we start off with a plastic material (such as PLA) in the form of a filament a couple of millimetres thick and we draw it into a heated extruder head which melts it to a malleable state. It is then deposited on a heated printing bed in a thin thread to start to build up the shape we require.

If you think of a conventional (or 2D) computer printer, it prints in two axes, side-to-side on the page (the X axis) and up-and-down the page (the Y axis). 3D printing adds an extra axis, the Z axis, which adds vertical thickness.

It does this by moving the relative position of the extruder head under tight control in those three planes.

Note that the expression is *relative* position. In theory this could be achieved by moving the extruder itself in the three dimensions. In practice, in this particular machine, the X and Y movements are both accomplished by means of moving the printing bed (on which the fabricated object will be built) backwards, forwards and from side to side, while the Z axis is dealt with by moving the extruder head up and down.

The frame is constructed from heavy-duty aluminium extrusion which helps maintain precision.

SPECIFICATIONS: Velleman K8200 3D Printer *(when completed from kit)*

Mechanical resolution:	X and Y:	0.015mm	(smallest step the printing plate can move in the X and Y direction)
(nominal)	Z:	0.781µm	(smallest step the printing plate can move in the Z direction)
Printing resolution:	Wall thickness (X,Y):		0.5mm
(nominal)	Layer thickness (Z):		0.20 - 0.25mm
Typical printing speed:	120mm/s		
Maximum print speed:	150 to 300mm/s (depending on the object to be printed)		
Extrusion nozzle:	0.5mm		
Extrusion thermistor:	NTC 100kΩ		
Extruded aluminium profiles:	27.5mm wide		
Movement:	4 NEMA 17 stepper motors		
Linear ball bearings:	8 and 10mm		
Technology:	FFF (Fused Filament Fabrication) for PLA and ABS		
FTDI USB 2.0 to Serial	Arduino compatible (Sanguino derived motherboard)		
Printable area:	200(L) x 200(W) x 200(H)mm		
Software:	Repetier version 0.84 and up		
System Requirements:	Windows, MAC or Linux computer to print from		
	An internet connection for manual and construction instructions.		
Power supply:	15V / 6.6A max.		
Complete unit size:	620(H) x 500(W) x 420(D)mm		

Imagine now that we want to fabricate a box. We need to arrange that the molten plastic is deposited on the print bed in a line of the given length, then at right angles, and again at right angles, again a third time, coming back to where we were. So far we have a thin layer of plastic shaped like a rectangle.

Now if we raise the extruder head slightly and repeat the process, the new plastic will be deposited on top of the old and we will have a slightly thicker line. Repeating this process over and over will build up the sides of our box.

Clearly, we need to ensure that the plastic is extruded at just the right rate (and the right temperature) and that the printing bed is moved in the X and Y-axes while the extruder head is moved in the Z-axis – all under tight control determined by the object we want to create.

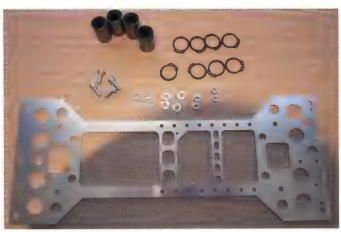
This is accomplished mechanically by stepper motors, toothed belts and cogs, controlled by an electronic unit itself driven by software. In particular, this form of what we call CNC (computer numeric control) operation makes use of the G code.

G code is a standardised form of issuing instructions to move tools by exact distances and in exact directions, as well as commanding such operations such as changing drills (CNC drilling machines), changing pens (CNC 2D plotters) or in this case, stopping and starting the flow of plastic from the extruder head.

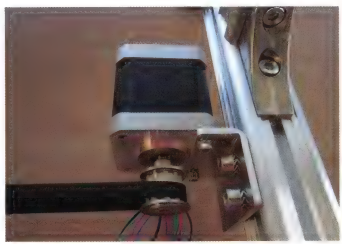
The stepper motor is a critical component in the movement in the three planes and in gradually building up the 3D 'image'. As its name suggests, a stepper motor, rather than rotating at speed, rotates in a more sedate manner and often by just a small fraction of one revolution as instructed.

The build

Let's now move on to the nitty gritty and start building. The first part of the machine to be built (at Chapter 1) is the simple spool holder assembly, which Velleman call the 'coil support' and which is used to support the spool of



Parts for the X-Y axis assembly.



The X-stepper motor in position, held by hex-head bolts and square nuts.

raw material (plastic filament). This is not a part with any critical dimension or even function; indeed some printers don't have a spool holder, relying on paying out the filament from a loose pile beside the machine.

Once built, the spool holder is put aside until the machine is virtually finished. So I think the reason for building it first is to accustom the user to the method of instruction accompanied by the excellent illustrations.

Actually I found that I tended to hit my face against the spool holder from time to time as I bent over the machine during construction, setting up and testing, so having fitted it when instructed I subsequently removed it until the machine was completely finished and calibrated.

The instructions break down the construction of the printer into easy chunks and all follow a similar format. The user is first instructed to take an easily identifiable major piece (such as part of the framework) or a bag of given number, in which case the parts inside are clearly listed and shown, both in words (usually) and by means of a clear illustration.

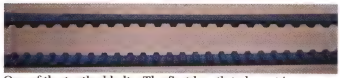
Usually, all the parts in a given bag are used in the construction step that immediately follows. In rare cases some of the parts are used later so before opening the next bag, if there are pieces left from the current bag they should be popped back in as the bag number will be referred to later.

Follow the instructions!

After the parts are listed, the detailed instruction for that step follow and often are accompanied by measurements where the rule or calliper comes into play. At this stage I should warn that the length of bolts is critical. If a 10mm M4 bolt is specified, don't fit a 15mm one or else you will find a later step cannot be accomplished. I found only one case where I had to reduce the size of bolts, as advised in Chapter 9 (using a file) where in fact I used a small grinder tool.

There are 20 separate chapters in the build section and a total of 858 high quality photographs accompanying them. These illustrations are not captioned as such but a glance further down the screen will reveal the photograph jpg number in each case.

This is in the format of chapter/illustration, eg 004/043 for Chapter 4, illustration number 43. I have used the same convention when discussing the steps.



One of the toothed belts. The first length to be cut is critical. Follow the instructions!.

Do you tend to skim (or even skip!) instructions and work by 'common-sense' like those people who proudly claim their method of testing an electronic item is to try using it before looking at the manual? That approach is not appropriate for this kit and will lead to much frustration as the build progresses. These instructions deserve very careful following to a precise degree.

If a washer is shown under a bolt, that is where to place it and not under the mating nut. If the instructions say 'do not tighten this nut yet' be sure to follow them — there will be a good reason.

Later, when you know more about what you are doing there may be one or two occasions where you can depart slightly from the exact instructions.

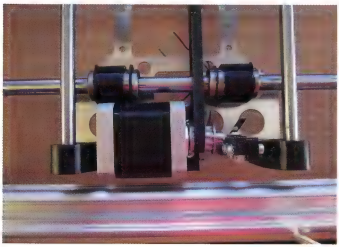
Don't force or over-tighten!

If a part doesn't appear to fit it is almost certainly the wrong part. Nothing should need forcing and nothing should require that last resort of the kit builder — the hammer!

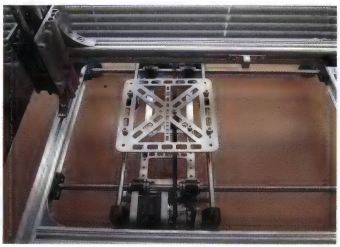
Also, if you are one of those 'no half measures' folk and especially if you often work on larger mechanical jobs like a car or bike, you must avoid over-tightening. Screwing up tight does not mean yanking the spanner with all your might until it's locked solid. Smaller diameter nuts and bolts will need much less force than the larger ones.

In this regard, the length of common right-angled Allen (hex) keys in particular is related to the leverage and force to be applied and for this reason I avoid those admittedly comfortable Allen keys with plastic T handles and rely on the traditional pattern of hex key as illustrated at the start of the instructions.

How far to tighten small fixings is largely a matter of feel and sometimes sad experience! A guide is the state of the star (spring) washer that is on most nut/bolt assemblies. Where tightening is instructed, the bolt and nut should be tightened so that the washer (viewed from the side) begins



Details of the X-Y axis assembly – linear bearings sliding on steel rods.



The X-Y axis assembly assembled and sliding smoothly!

to be noticeably compressed but not screwed hard down so that it cannot be moved any further.

I found that all the parts but one were of very high quality. The one exception was an adaptor that secures a threaded rod to the Z stepper motor, which I found to be minutely eccentric, although perfectly usable. I did find that some of the aluminium plates had sharp edges in one or two places and this was improved by a very light application of a file.

As you will find as the build progresses, the framework is made of cleverly extruded aluminium in which square nuts are located as required to locate numerous other parts, with the aid of cast corner pieces or plastic mouldings.

The plastic mouldings are themselves of precision manufacture with no 'slop' whatever detected in fitting. The X and Y print bed movements are accomplished by moving the carriages smoothly with the aid of linear bearings running on precision ground bars. The Z movement is by courtesy of a rotating lead screw

The copious instructions and photos are very nearly perfect. I'll mention the rare problems that I found in the order that they occurred.

One general anomaly is that although at first the terms 'bolt' and 'nut' are correctly used to mean male and female fasteners respectively ('screw' being sometimes used in Australia to mean 'bolt'), they are reversed in some of the instructions (but not all of them). The illustrations make it clear when a 'nut' is really a bolt and vice versa!

Linear bearings and circlips

At 002/011 and subsequent illustrations in this chapter we have our first introduction to linear bearings. The plastic holders are of high quality as already mentioned but an even greater degree of precision is given by the inserted linear bearings which will later slide on the bars. These bearings are secured using circlips in grooves and it is worth repeating the caution that they should only be fitted using proper circlip pliers that locate in the circlip end holes.

If you've never used circlips before, you need to remember that their flexibility is limited. The correct way to apply one is to engage the circlip pliers in the small holes, then offer up the circlip to the shaft or in this case bearing and gently squeeze on the pliers just enough to allow the circlip to slide onto the bearing, until it locates in the groove provided. Tension is then released and the clip should click into place.

Aligning the bearings

As instructed, you will not at first fully tighten the plastic mouldings onto the X plate but it is helpful to align them by eye. This will be refined when the bearing bars are fitted, and the aim is to allow a smooth sliding movement over the bars, before attempting to tighten the fixing bolts. The same applies later with the other linear bearings.

By 002/064 we come to the mounting of the first of the four stepper motors. This was one place where the design was found to be good rather than excellent, in that the wires to this motor pass through the aluminium plate that makes up the X carriage rather close to the edge of the provided hole (002/068). Care needs to be taken that the wires do not chafe here.

When it comes to 002/072 and successive illustrations, you need to be very careful about two things. The instruction rightly emphasizes that there should be exactly 127 teeth in the 63.5 cm length of belt that you cut. The length of this piece of belt is indeed critical and the old adage 'measure twice and cut once' comes into play!

Also you need to be careful tightening the clamp. Although mindful of my general warning (and previous experience), I still managed to over-tighten my belt clamp and break it. What I should have borne in mind is that the clamp presses against an inherently flexible material - viz rubber - and an even more gentle hand is required as tightening never reaches the invisible 'wall' that we instinctively aim for!

Fortunately, spare belt clamps were included in the number of parts I had left over!

Care with exact measurements

A good example of the care that needs to be taken over the correct choice of plastic parts is at 004/008. In fact there are several pieces of very similar appearance but only some have the 10mm recesses required at this stage while others have 8mm. The illustration emphasises this in red.

First anomaly

In Chapter 7 I came across the first real anomaly. The instructions for fitting the Z motor bracket are that the bottom of this bracket should be fitted at a height of between

I managed to break a belt clamp – fortunately there were spares.

They look alike but some are for 8mm rods while some are for 10mm rods.

4cm and 4.5cm from the top of the frame, and illustrations 007/008 to 007/011 confirm this. But by 007/016 the bracket is shown level with the top of the frame, with the fitted motor correspondingly lower.

That new position is shown in later illustrations such as 007/022. However, if you fit the motor in the lower position as I did, you will find that near the end of the construction it becomes apparent that the Z axis end stop microswitch will not be actuated until the extruder head has collided with the print bed! The higher position is the correct one!

Incidentally, the instructions preceding 007/008 emphasize the need to ensure that the Z motor bracket is fitted perfectly horizontally. The reason for this is that the threaded Z rod to be added to the motor spindle in due course will not fit or run correctly as it won't be truly vertical if the bracket is even slightly out of kilter.

This is where the spirit level comes in and by the way, it is not good enough to have the bubble 'about' in the middle of the sight. It must be *exactly* in the middle (assuming that the workbench itself is also level)! If the spirit level refuses to settle down, there may be a small manufacturing pip on the bracket (in which case carefully file that down).

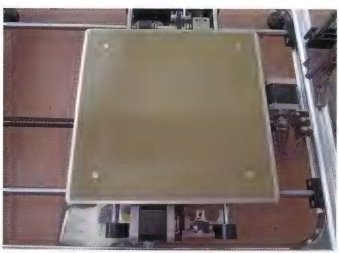
At 008/007 there is an instruction to '...take *the* short M5 bolt...'. This is better understood as '...take *a* short M5 bolt...', since there are three in bag 28, as shown in 008/001. (The other two are used at 008/015 to 008/017).

At 008/012 and 013, the instructions again indicate that the motor bracket should be perfectly horizontal. A small spirit level is of course helpful here – if not essential – but you may find that it is irritatingly difficult to set, as I did. This may well require a manufacturing pip to be carefully filed off so that the spirit level will seat correctly.

At 009/068 the illustration shows Philips head bolts but those supplied in my kit were much better hex head ones, a sign that the instructions and/or kit are subject to continuous improvement.

At 012/014 I found (for the one and only time) that the M3 bolt was just too short. I had to relieve a lip on the side of the microswitch as well as omit the flat washer.

At 012/016, the illustrations show the microswitch secured through the hole nearest to the switch pivot. This was one case where I departed from the instructions as the far hole positioned the switch more appropriately in relation to the actuating screw on the X carriage.



The heated print bed. If not perfectly flat, it can be pressed until it is.

Relief for electronic people

At Chapter 15 we begin the all-important wiring process. Subsequent instructions call for the stripping and tinning of various wire ends, followed in due course by joining them. Since successfully soldering together two already tinned wires can require three hands, I have a preference for twisting joints together first and then soldering them.

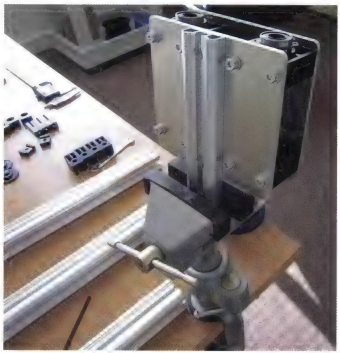
As you will see, all soldered joints are covered by heat shrink tubing. Most electronics enthusiasts have had the experience of soldering (often one of the older multiway connectors) and then realising that they had forgotten the end cap which should have gone on the wires first! This is the mistake you only make once or twice! Similarly, remember to place heat shrink sleeves over the wires before soldering joints. Again, clear and illustrated instructions are given to this effect.

A minor anomaly in the instructions concerns the colours involved in the occasional need to snip off the middle wire on a three wire polarised header. For example, in 016/028 this is said to be orange but on my 3-way connectors the middle wire is in fact red, leaving orange and brown connected. In 016/035 the connections should therefore be (in the order of ribbon cable to connector cable): red --> orange, and brown --> brown. This also occurs at 017/021 and 018/057.

018/002 the instructions say '...twist the wires from Group 2 and 3 together'. It would be clearer to say '...twist the wires from group 2 together with each other as well as the wires from group 3 together with each other...', as shown in 018/003.

In 019/043 the larger heat shrink sleeve should be first placed over two wires from the hot end and not four.

At the end of the build I had several parts left over. These included an extruder head thermistor (very thoughtful as this part is easily damaged), six square nuts, a couple of washers and in particular, quite a few plastic mouldings



Assembling the Z-axis bearing carriage. A bench vice is very handy here.

(three of which were belt clamps, an easily broken part). There were no parts missing during the build, but despite being careful with recommended lengths I did run out of heatshrink sleeving just before the end (thankfully I had a stock).

Setting up and printing

We now move on the various tests, downloading and setting up software and finally printing an object!

These activities are described under 'Start Printing' at www.k8200.eu/manual/printing

There are seven chapters in this section, this time starting with Chapter 001 and finishing at Chapter 007.

Chapter 001 The Basics: This is a brief summary of the basic principles involved in 3D printing.

Chapter 002 Connecting the printer: This chapter starts with instructions on downloading the USB driver for the controller board, that for Windows being downloaded from http://ftdichip.com/Drivers/VCP.htm (at the time of writing, drivers for Mac and Linux were under development). This is a Zip file so be sure to extract before you try to run it. That process finishes with establishing which COM port will be in use for the controller board.

After connecting the controller board to the computer via the miniature USB plug, you will find that red and green LEDs on the board come on.

Once that is done, the next step is to download the main software for operating the 3D printer. This is found at www.repetier.com. At the time of writing, the Velleman notes recommend using version V0.84, although the instructions may change in due course as there are now later versions available. This file is valid for Windows, Mac and Linux. The download process ends with the placing of the Repetier icon on the desktop.

There are then detailed Repetier instructions for setting the COM port (which you have noted earlier) and various parameters on the printer, such as the dimensions of the workpiece, temperature of the extrusion head and print bed.

Note that so far the controller board has not been energised (apart from incidentally via the USB port). The illustrations of the 15V DC power supply that follow (002/010 to 002/016) show the mains lead (after the outer sleeve has been stripped) being wrapped around a ferrite filter. The power supply unit that I received already had a filter built in, so a much shorter length of wire had to be stripped.

When connecting the power supply, at 002/019 there is a warning that if "anything happens when you do this, disconnect the supply immediately". Certainly at this stage no motors should operate but in fact something *should* happen and that is that the red and green LEDs (which come on when the USB port is correctly connected and configured) should now go off.

When it comes to 002/025, Adjusting driver voltages, the parts involved are extremely small and you will note at 002/030 that three hands are necessary to carry out this task. The easiest — delegated to my assistant — was holding the negative probe of the test meter in contact with the negative DC supply screw. Extreme care is needed when holding the positive probe on each driver sub-board via, when the tip of the finest probe looks as delicate as a telegraph pole under a lens, in comparison with the job at hand!

The actual adjustment of the driver voltage is very tricky. Unless you have just the right tool there will be considerable backlash. The recommended voltage is 0.425V but note that striving for the last digit is pointless. For example, an error of 0.005V here amounts to about 1% — meaningless — and ±5% (reasonable) would take the setting from 0.404V to 0.446V. Indeed, we are instructed that any of the three motor drives may be increased to as much as 0.550V (approximately 29% higher) if the motor mechanical linkages are too stiff for the setting first recommended. This is more likely on the Z axis where the trueness of the threaded rod adaptor is critical.

Tests

We now come to tests via the Repetier software, notably movement of the motors and positioning gear. If you have wired everything correctly, then these are very satisfying and in my case went without a hitch.

During this setup process (in 002/068) you are asked to move the print bed completely to the left. How far, I wondered? Against the frame or to line up the print head with the extremity of the bed?

The answer is that it doesn't matter at this time because the only reason for moving the bed to the left is to allow room to test the X motor microswitch (on the right). Similarly for the Y microswitch (at the back). When testing the Z microswitch you have more time/room to carry out tests as

The Z-axis arm in position, with three guide rods.

The extrusion head carrier components, including the main bolt and bearings.

A small torque wrench with 13mm socket is advisable for setting the hot end.

the Z movement when the lead-screw turns is much slower.

Do not allow yourself to be distracted during these tests or failure to stop the motor travel may cause collisions or even injury!

At 002/079 at the end of the tests on the Z limit microswitch, you are told 'If the microswitch is working correctly the Z carriage will stop.' The X and Y movements do instantly stop when their respective microswitches are operated but the behaviour of the Z carriage is slightly different. When the microswitch is operated it first stops and then immediately backs off (up) a couple of millimetres. This was confirmed as normal.

Calibrating the printer

In Chapter 3 we move on to calibrating the printer. As the instructions say, this stage is critical to good print quality.

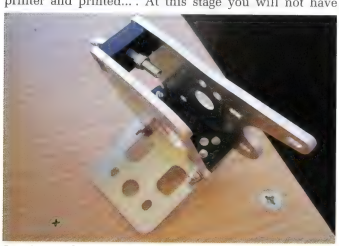
I did have problems here with my Z motor stalling with a buzz when the print head was still some millimetres from the print bed — probably caused by the very slight eccentricity of my threaded rod/motor adaptor — despite resetting the Z motor potentiometer to 0.55V (the permitted upper limit explained in just before 002/031).

I worked around the problem by re-positioning the print head arm assembly down a few millimetres in the frame so that the print head was closer to the print bed while the Z nut was not quite so far down on the threaded rod.

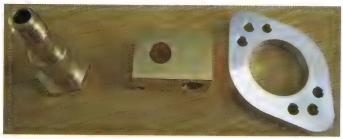
I also found that my print bed was not quite flat which was initially frustrating. However, there is a critical sentence in the penultimate paragraph 'The heated bed, cardboard isolator and aluminium bed plate can be forced a little bit until the bulge in the middle is gone.' As advised earlier, brute force techniques should never be needed or employed in this build, and I found that judicious pressing on the centre of the print bed was effective in due course

Configuring Slic3r

There appears to be a minor error in the first sentence of Chapter 4, which reads 'After you have calibrated your printer and printed...'. At this stage you will not have printed so those last two quoted words can be deleted.



Starting on the extrusion head carrier.



Some of the hot end components. In use they become hot!

The configuration file K8200-PLA-STANDARD "download" will be found at www.velleman.eu , navigating via support > downloads where you will find K8200-PLA-STANDARD.INI This is a Zip file and you will need to extract it before loading it into Repetier as instructed.

You now set the print, filament and printer settings to match the Velleman printer, save the settings and that's the configuration done.

The first print

Velleman have chosen for the first print a fairly ambitious model, being a cover for the controller board on the printer itself.

I say 'ambitious' not because the model is particularly complex but because it is fairly large, uses quite an amount of PLA filament and takes a long time to build.

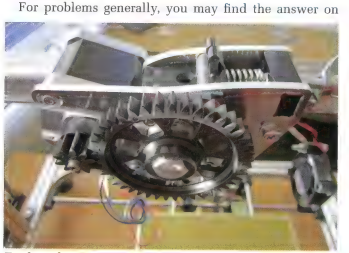
At 005/011 you are instructed to download the K8200BOARDCOVER.STL file, which you will find at www.k8200.eu/support/downloads or at www.thingiverse.com where it is thing No. 15524. STL can either stand for STereoLithography or Standard Tessellation Language and is the native 3D file that specifies the solid model exactly and in a form which Repetier can slice (via Slic3r) and interpret into the G Code that actually controls the printer.

Again, this is a Zip file, so will need to be extracted. Pressing the LOAD button on Repetier now results in a navigation pane from which you can access the newly extracted STL file.

Of course you are not limited to the one model! There are a host of STL files available on the net, an especially good selection being found at www.thingiverse.com/

Problems?

For problems generally, you may find the answer on



Feed mechanism taking shape!

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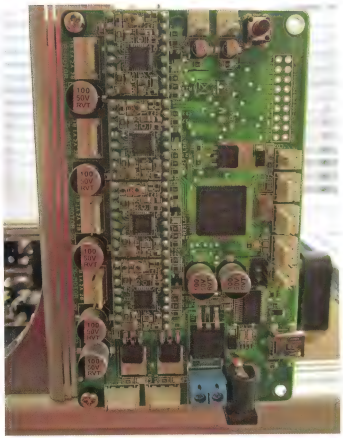


The controller board. All wiring terminates here, mostly on polarised headers.

the excellent forum which can be found at http://forum.velleman.be/ There, beginners and old hands exchange information and you are likely to find a post from someone who has had the same problems as yourself as well as the solution.

Conclusion

This has been a marvellous journey lasting several days, and like many journeys the joy has been in getting there – making it – even more than in the successful arrival. Apart from very minor instruction anomalies easily overcome with commonsense, the instructions have been accurate, detailed and helpful. The copious illustrations – hundreds of them – have been extremely effective in clarifying the steps to take.

I have no hesitation in warmly recommending this kit. The components are robust and extremely well made. Building the Velleman K8200 printer is a major project that will provide hours of enjoyment, a notable absence of frustration and will result in a practical machine which will reward continuing study and experimentation.

The 3D printing world has not yet fully matured so you get a feeling of pioneering when using the finished item. At the same time this is no flimsy and partly thought-out kit. It will form a solid basis for further learning.

Where from, how much?

The Velleman K8200 3D Printer we reviewed came from Jaycar Electronics and is available at all Jaycar stores, re-sellers and online (www.jaycar.com.au). The kit retails for $1299.00 (Cat No TL4020). SC

Introducing: 'The Currawong'

By LEO SIMPSON & NICHOLAS VINEN

A 21st Century, All-Australian Audio Amplifier featuring both Valve and Solid State Technology

The Currawong is a paradox: a stereo amplifier design that's as modern as tomorrow but uses a 1950s-era valve power amplifier design! It has a power output of around 10 watts per channel into 8-ohm loads and is mainly built on one PCB. Using the tried and tested ultra-linear class AB configuration with four valves in each channel, it would be a great match for our recently-described Majestic 2-way loudspeakers.

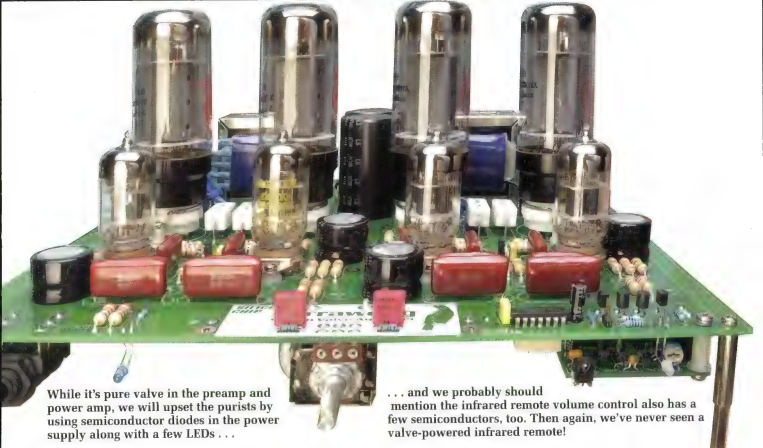
We have had this amplifier under development for about six months but it has been the subject of lively discussion in the SILICON CHIP offices for considerably more time than that, with extra stimulation from occasional correspondence from readers with a deep desire to build and own a modern valve amplifier.

And while it might have seemed as though we have ignored these plaintive requests, we have had it in mind to "do something" about a definitive "modern" valve amplifier, if only to finally settle the debate about the relative merits of solid-state versus valve amplifiers.

Well, this amplifier is ultra-modern in a number of respects. It uses a large double-sided PCB with plated-through holes for virtually all of the circuitry, apart from a small daughter board for the infrared remote control and the connections to the power transformers. It also uses very compact modern PC-mount electrolytic capacitors for the high voltage filter and bypass capacitors.

No electrolytics are used for signal coupling. Instead, we have employed dipped polyester (polyethylene terapthalate) capacitors for the high voltage signal coupling and MKT

We believe this to be very close to the final PCB layout, although there may be some minor component changes as we tweak performance. Apart from the power transformers, almost everything mounts on one double-sided board.



While it's pure valve in the preamp and power amp, we will upset the purists by using semiconductor diodes in the power supply along with a few LEDs . . .

. . . and we probably should mention the infrared remote volume control also has a few semiconductors, too. Then again, we've never seen a valve-powered infrared remote!

polyester capacitors for low voltage signal coupling.

And all the low power resistors are modern 1% tolerance metal film resistors. The valve line-up in each channel consists of two 12AX7 twin triodes and two 6L6 (or KT66) beam power tetrodes.

So apart from the valves themselves, the components are modern and far superior to those available in the heyday of these amplifiers.

The Currawong circuit

So what does the circuit configuration look like? Since the amplifier is still in the development and testing stage, it is too early to publish the circuit. We aim to do that – and present the construction details – very soon.

However, by sheer coincidence, this month's Vintage Radio section carries an article about the restoration of a Mullard 5/10 valve power amplifier (see pages 92-97).

This was a highly-regarded mono amplifier for hobbyists that was first published in 1954. Two were needed for stereo operation. A stereo version, the Mullard 10-10, was produced much later, with a very similar circuit arrangement but instead of 6L6s in the output stages, it used 6GW8 triode-pentodes. It also used two large PCBs, one for each channel.

It just happens that the circuit arrangement of the 60-year old Mullard 5/10 is very similar to that of the Currawong, except that the Mullard valve line-up includes an EF86 pentode as a preamplifier stage rather than the 12AX7.

Preamplifier stage

With regard to the preamp stage, we can be much more specific because it is based on the 12AX7 valve preamplifier published in the February 2004 issue of SILICON CHIP, with only slight changes to the component values.

In brief, the preamp is a two-stage design with negative feedback applied from the plate of the second triode to the cathode of the first. The heaters for all four 12AX7s are fed from a regulated 12V DC supply, to ensure low hum.

Power amplifier stage

Following the preamp stage, the circuit of the Currawong is conceptually very similar to that of the Mullard 5/10.

The two 6L6s drive an output transformer in Class-AB mode, essentially meaning that one valve handles the positive half (or swing) of the signal while the second valve handles the negative swing, similar to a transformer-coupled Class B transistor output stage.

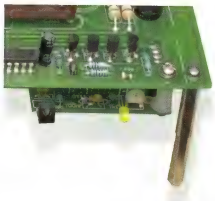
The transformer primary is centre-tapped and the primary leads are connected to the respective plates (anodes) of the valves. Thus the transformer provides the high voltage DC to the plates but the magnetic fields produced by the separate valve currents are cancelled in the transformer core; otherwise it would be liable to saturate.

Since the output stage works in push-pull mode, the signals to the grids of the two output valves must be out-of-phase (ie, 180° phase shift between them).

These out-of-phase signals are derived by the two triodes within the second 12AX7 in what would be regarded today as a "long-tailed pair" (similar to a 2-transistor differential amplifier). An "in-phase" signal comes from the plate of the second triode, while the out-of-phase signal comes from the plate of the first triode.

The input signal to the "long-tailed pair" is fed to the grid of the first triode while the grid of the second triode is effectively grounded. This will be fully explained in the circuit description (when we publish those details).

The other significant feature of the output stage is the "so-called" ultra-



As a concession to 21st century operating convenience, this little remote control PCB (shown at left very close to life size) is suspended underneath the main PCB (shown in situ at right). It employs a microprocessor to control a motor-driven volum potentiometer, also suspended under the main PCB. Of course, if you *must* have genuine 1950s operation, you could always substitute a standard pot . . .

linear output connection whereby the screens of the tetrodes are connected to 80% taps on the primary of the transformer. This is (and was) a very highly regarded configuration providing much lower distortion.

There is also limited negative feedback from the secondary of the output transformer to the cathode of the second valve in the 2-stage preamplifier. Again, all of this is quite similar to the configuration of the Mullard 5/10.

The valves

Like most valves these days, those in The Currawong are of Russian manufacture, typically branded Sovtek or electro-harmonix and available in Australia from Altronics Distributors or Jaycar Electronics.

Our initial results show that the harmonic distortion will be quite low (maybe around 0.2% in the mid frequencies), about what we would expect.

But the amplifier will be particularly quiet, mainly as a result of the DC fed to the filaments of the small signal triode stages. Any more detail about performance will have to wait until the final amplifier design is present, maybe in a month or so.

The power supply is based on two toroidal power transformers, one to supply the AC and DC rails for the valve heaters while the other provides the DC HT (high tension) rails for the valve plates (or anodes).

And while the 12AX7 heaters are fed with DC from an adjustable 3-terminal regulator, the HT rail is also a departure from 60-year old practice.

In this case, the DC supply is derived from two 1000V silicon diodes and two 470µF 400V capacitors in a voltage-doubler configuration to develop about 310V DC.

This configuration is very similar to that used in valve TV sets produced in Australia in the 1960s. Our up-date of the circuit is to feed to the DC from the voltage doubler to a 3-transistor capacitance multiplier which greatly reduces the 100Hz ripple on the HT rail. This also contributes to the general quietness of the amplifier.

The valve line up consists of two 6L6s (left) and two 12AX7s in each channel.

This part of the circuit also provides a switch-on delay for the HT rail so that no DC is fed to the valves until their filaments have provided a suitable preheating. Both these features could have only been dreamed of in the 1950s.

Mind you, these measures will have little effect on the overall quality of the "valve sound" apart from the overall quietness. We hope the purists won't mind...

Other refinements

While there are no solid-state devices used in the signal path in the main amplifier, we have made some concessions to 21st Century operating convenience.

In other words it will have an infrared motor-driven volume control that is quite similar to the volume control for the Ultra-LD Mk3 amplifier (See SILICON CHIP, November 2011).

The only other "refinement" worth mentioning at this stage is that we have added blue LEDs on the PCB to illuminate the output transformers. This is purely a cosmetic feature. Again, if the purists don't like the LEDs ("but LEDs weren't invented in the 1950s!"), they could be omitted.

Mention of the transformers brings us to the other interesting feature of this amplifier. As old-time valve amplifier enthusiasts will attest, the output transformer was always the most critical and most expensive component in a high quality circuit.

It still is. In fact, high quality ultra-linear output transformers typically run to several hundred dollars each! Gulp.

And this is the interesting feature. We have employed standard 100V line transformers normally used in PA amplifiers. Conveniently, we are able to use the power taps on the transformer for the screen connections to the tetrodes.

Intrigued? It works quite well. But you will have to wait patiently until we have fully checked the final design.

Until then, stay tuned... SC

Electrolytic Rust Removal

By Dr David Maddison

Got something old and rusted lying about that you'd rather have old and not-so-rusty? We cannot promise miracles but you might be surprised how easy it is to restore rusted items to their (somewhat!) former glory!

There are plenty of objects around most homes that would benefit from rust removal, for example old tools, old car or engine parts for use in restorations, components of antique electrical items (eg, a rusted battery holder), garden furniture and many other items.

And there are many methods and products to remove rust, which have various levels of success.

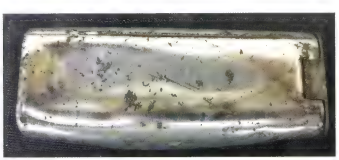
Common methods include mechanical techniques in which rust is removed by the abrasive action of sandpaper, a wire brush or high speed particles from a sandblaster; or chemical techniques in which rust is removed or converted to something more stable by a chemical agent such as an acid.

All these methods have some disadvantages, such as the removal of good metal – not just the rust – or the conversion (but not removal) of the rust to something more stable, thus losing information as to the original shape of the object and obliterating features such as markings in the original metal. In addition, proprietary chemicals for rust removal or conversion can be expensive and somewhat toxic.

The aim is to restore the artefact to as close to original condition as possible, not just make it look pretty!

Another promising method of rust removal that has increasing popularity

This rusty mint tin was found by the side of the road. It's not in the best of condition . . .



. . . but after treatment, came out quite well. The paint was removed but that's usual with electrolytic rust removal.

APPLICABILITY OF METHOD

While this method has been widely tested by numerous people and in various places, as with any new procedure, before using it on an important object, you should test the process in your particular circumstances and with your own setup on a test part for which it does not matter if the process does not work to expectations.

This article deals specifically with mild steel items that have rusted in air (due to the action of humidity or rain) or have been submerged in fresh water or have been buried in soil.

A slightly different and more sophisticated method is required for the restoration of items that have been submerged in seawater for long periods. Since such artefacts (eg, ancient cannons and anchors such as from the HMB Endeavour) are likely to be in the realm of marine archaeology, this topic will not be discussed here. Suffice to say, with such artefacts it becomes very important to remove the chloride ions from the rusted artefact which takes a long time and the chloride levels coming out of the artefact need to be monitored until there are no more.

In addition, a different electrolyte chemical is used in the case of objects rusted by salt water – for example sodium hydroxide instead of sodium carbonate.

that does not seem to affect the original metal is to use molasses; however this takes a very long time. Interested readers may wish to Google this.

Electrolysis

Apart from the above methods, there is another way. It involves the use of electrolysis to remove rust. This method only removes rust and leaves the base (un-rusted) metal intact.

It may also reveal many details in the original metal such as patterns or stampings of numbers and letters which seem completely obliterated by the rust, which may not be preserved using other methods.

This method has also been known to restore items with moving parts which were rusted solid and thought to be completely beyond hope of restoration to working condition.

The method is simple and inexpensive and involves only household items, apart from a low-voltage power supply or maybe a car battery charger, which most SILICON CHIP readers would likely own anyway.

The details of the method will be discussed in detail later but in essence, a container holding an aqueous solution of a common chemical is set up with two electrodes and a power supply, thus establishing an electrolytic cell.

One electrode, the anode, is made of mild steel and is gradually sacrificed in the process. The other electrode is the iron/steel piece under restoration.

Note that **rust damage is permanent.** This method will remove rust but no method will return original metal that has disappeared. It is best to store and maintain tools and other items in an appropriate way to prevent them rusting in the first place.

What is rust?

Before discussing the electrolysis process it is necessary to first discuss the nature of rust.

Put simply, rust is iron metal combined with oxygen to form chemical compounds known as various forms of iron oxide.

The chemical reaction by which rusting occurs is an electrochemical one, since the flow of an electric current is involved. Iron loses electrons and both oxygen and water take up electrons and iron metal chemically combines with oxygen.

The rusting of iron is said to be an oxidation reaction. In effect, this process forms a type of galvanic cell.

In the process to be described, the objective is to reverse this rusting process (to the extent possible via an electrolytic process) via the opposite of the oxidation reaction, called the reduction reaction.

An electrolytic process is the opposite of an electrochemical one. In an electrochemical process reactions are spontaneous (eg, rusting) but in an electrolytic one, reactions only occur when energy in the form of an electric current is supplied.

There are several forms and colours of iron oxide, depending upon the conditions of formation. To form rust, iron or steel requires contact with both oxygen and water and if salts or salt spray is present, rusting occurs much more quickly.

Red rust

The most destructive type of rust is the loose, poorly adherent, flaky, porous material which occurs on severely rusted items.

This rusted material has a significantly greater volume than the original metal from which it is derived. When it happens in a constrained space, such as with reinforcing bars set in concrete, its expansion causes destruction of the surrounding material (a condition commonly known as "concrete cancer").

The rusting of this material is non-reversible and represents a complete and permanent loss of the original metal.

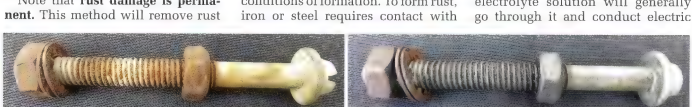
This type of corrosion is often called "red rust" and generally has the chemical formula $Fe_2O_3{\cdot}nH_2O$ (hydrated ferric oxide) when the process has occurred in the presence of oxygen and moisture.

This material has minimal or no electrical conductivity.

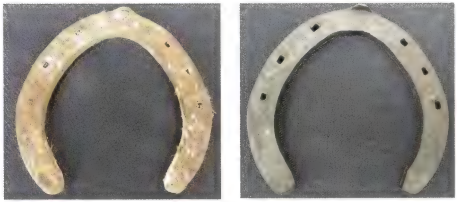
The non-hydrated form of this compound is the mineral haematite, from which iron is originally derived.

Because of the limited electrical conductivity of this type of rust it is mainly unaffected by the electrolytic process in terms of reducing it back to iron.

However, because it is porous the electrolyte solution will generally go through it and conduct electric



This rusty nut and bolt combination was first processed as one piece as one nut had seized. After a period of electrolysis the nut could be removed and the pieces were processed separately.



This horseshoe was buried in the ground for at least 90 years. It cleaned up very nicely. If the same horsehoe had been in seawater even for a relatively short time, treatment would be very much different and probably not as successful.

current to the base metal. This is significant and will be discussed later.

When the rust is not so severe that loose flakes of rust are generated, this same type of red rust may still be present but may in the form of small "islands" of rust, or as a thin continuous coating all over an object.

While not necessarily being strongly adherent, it can still be difficult to remove.

This is possibly the most familiar form of rust and may be present on tools or other objects that have been left in the open but not for so long that the aforementioned type of rust can develop.

Black rust

Beneath the red rust and above the original uncorroded metal is usually a layer of "black rust" which has the chemical formula Fe_3O_4 (iron(II,III) oxide or more commonly ferrous-ferric oxide) and unlike red rust, this form of rust does not occupy a significantly greater volume than the base metal from which it was derived. Therefore it is adherent and does not flake.

This layer is somewhat protective and may preserve some details such as decorative stamp marks from the original metal.

It may be possible to revert this material back to unoxidised (unrusted) metal by the electrolytic process described here. This reaction to convert the oxide back to metal involves the iron atom gaining electrons and losing oxygen.

Should you remove rust from antiques?

As a general rule, antique objects are often significantly devalued by attempts to clean them, including the removal of rust.

Collectors appreciate the original "patina" of an object so if you have a genuine antique, you should consult an appropriately qualified antique expert as to whether the object should be cleaned or left as-is. Our experience suggests the latter.

This black rust is electrically conducting and magnetic and is also known as the mineral magnetite.

The electrolytic process

During the electrolytic process, a power supply causes a current to be passed via an electrolyte (a solution which will conduct electricity) between the item under restoration (the cathode, connected to the negative terminal) and a sacrificial anode (connected to the positive terminal).

At the cathode, which is the rusty object to be restored, it is hoped that as much of the oxidised iron as possible is reduced to iron metal. As explained above, not all rust (such as most of the flaky red rust) can be reduced in this way (although some may be reduced to black rust) but the black rust, between the original metal and the red rust, mostly can be.

What can be reduced back to metal will be although this will mostly be poorly adherent as will most of the rust remaining after treatment and it will fall away or can be brushed away.

As pure water does not conduct electricity to any significant degree, an electrolyte chemical is added to the water to make it conduct. The electrolyte chemical is chosen on the basis that it does not itself have adverse reactions that interfere with the process.

Washing soda, also known as soda ash or sodium carbonate, Na_2CO_3 is most commonly used in this process and is the basis of this description.

It is safer to handle than the other frequently used electrolyte, sodium hydroxide, NaOH, which is often used with restoration of marine artefacts.

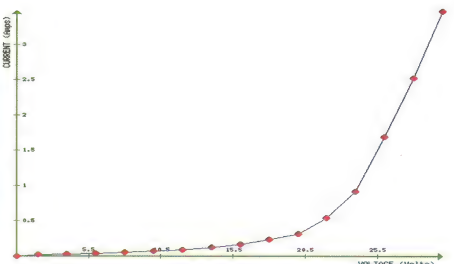
Oxygen gas is evolved at the sacrificial anode and hydrogen gas is evolved at the work piece (cathode).

As hydrogen is inflammable and both gases together are explosive, the container in which electrolysis is done must be wide-open and the procedure must be done in a well-ventilated, open area free of ignition sources.

The formation of hydrogen gas bubbles within the rust layer also helps to mechanically clean the part as the expanding gas bubbles within the porous rust cause pieces of rust to be pushed off.

(Above): A heavily rusted item (railway spike), shown at right being processed. Note the evolution of gas from the item. During electrolysis rust flakes fall away from the object as shown. This item did not start to electrolyse at first, so the voltage was increased to break whatever barrier was causing the high resistance that was preventing electrolysis and then the voltage was lowered.

Washing soda (sodium carbonate) as used for the electrolyte. It is available in the laundry section of most supermarkets; swimming pool 'pH increaser' from pool shops or hardware stores can also be used.



A plot of current versus voltage for one sample showing how the current starts to rapidly rise at a certain point corresponding to a rapid increase in the chemical reactions occurring. The reactions include the reduction of various iron oxides and gas evolution corresponding to the electrolysis of water. The current decreases as any new voltage increment is adjusted to so these currents are recorded at the moment that the new voltage is set.

As the sodium carbonate is not significantly consumed in the process the solution can last indefinitely; it only being necessary to top up the water lost due to evaporation or gas formation. However, sooner or later the solution will become brown with rust and will need to be replaced.

While the solution is not especially toxic if only mild steel has been used in both the cathode and the anode, it is wise to consider where to dispose of it. (Some plants might not like an iron rich soil, for example.)

Experiment with the process to see what you can do. For example, for long parts like saw blades you can use PVC plumbing pipe as a container. Or for cleaning in tight places like an engine block you could try putting a wire anode inside a hose with lots of small holes in it or a permeable drip hose to get the electrode close to the work part.

In such cases pay extreme care to the build up of oxygen and hydrogen in confined places and take appropriate precautions. For parts that cannot be submerged, perhaps a sponge soaked in electrolyte can be used to make contact with the part to be cleaned.

The sacrificial anode

The sacrificial anode should be made of mild steel and should surround (but not touch) the object under restoration to ensure that the electric field on the object is evenly applied.

The sacrificial anode is eventually dissolved so make sure it is a scrap piece. Platinum (extremely expensive) or graphite can also be used for the anode and will not dissolve like mild steel.

While certain grades of stainless steel can theoretically be used for the anode, they should be avoided because of the possibility of highly toxic and carcinogenic chromium ions being released into the solution.

Part of the anode should be above the liquid level and this is where the electrical connection to it is made. If it is made within the liquid the connector will be destroyed.

The metal of the sacrificial anode should not be coated. Commonly available materials that are suitable include scrap uncoated sheet metal from car body work and uncoated steel reinforcing bar and mesh.

A scrap piece of rebar mesh was used for this story and was obtained free from a nearby building site (with permission!).

The mesh (shown in photo opposite) was galvanised so the coating was removed below the electrolyte level. Most rebar you see on building sites is uncoated and has that characteristic red rust colour from being exposed to the elements for a while.

SAFETY AND OTHER PRECAUTIONS

Both hydrogen and oxygen gas is generated with this procedure. In combination, these gases can be explosive. Also, oxygen by itself enhances combustion. This procedure MUST be conducted in a well-ventilated area, away from sources of spark or flame (eg, don't smoke anywhere nearby!).

Turn the power supply off first before connecting or disconnecting wires to avoid sparks.

For the sacrificial anode, only use mild steel (or graphite or platinum if you can afford it!). Do not use stainless steel as toxic chromium will go into the solution, even from 316 grade under certain conditions. This also creates a disposal problem. Do not allow the liquid solution to splash on the power supply or other electrical devices.

As with all chemical processes, use safety glasses and latex or other protective gloves as per good practice. Do not use this process if you are not comfortable with using electricity or chemicals or are not confident or understanding of what you are doing.

If it is a valuable or rare part you are treating, try the process on a non-valuable item first to ensure the process works to your satisfaction.

Make sure the correct polarity is used as the incorrect polarity will destroy the part you are trying to treat.

The setup (left), including a look inside 'The Bucket' (above). Note how the sacrificial anode surrounds any object to be treated. The water becomes rust-coloured as shown. The black wire is for attachment to the object under restoration (although there is no item shown here) and the red wire goes to the sacrificial anode.

To form the rebar mesh into a cylindrical form it was found to be convenient to place it diagonally across a stone gutter and strike it with a heavy club hammer in the unsupported area, gradually moving along the length of the piece.

Doing a bit at a time, the flat mesh was gradually transformed into a cylindrical electrode. Of course, thin sheet metal would be much easier to shape.

Coated steel can be used as a sacrificial anode but make sure to sand off the protective coating first.

The anode is where the process of oxidation takes place (electrons are removed from the chemical structure).

Electrical connection to the item under restoration

It is important that a good electrical connection is established to the item under restoration.

For a severely rusted item with a thick layer of insulating rust it may be necessary to scrape or grind away some rust to get down to original metal with which a good electrical connection can be made.

Alternatively a powerful, good quality alligator/crocodile clip could be used if it has enough 'bite' to get through the rust layer. It may have to be moved side to side to help it 'dig' through the rust to establish a good connection.

Another possibility is to fabricate some type of clamp with sharpened contact points that, when tightened, will go through the rust layer and make contact with the base metal. You can test how good the connection is with a multimeter.

The electrolyte

The concentration of the electrolyte solution is not critical but a 5 to 10% solution by weight seems to work well. The percentage by weight for a certain volume of solution is determined by the mass of the solute (matter to be dissolved) in grams divided by the volume of solution in ml, all times 100.

To have one litre of a 10% solution of washing soda (Na_2CO_3) it would be necessary to have 100 grams of the soda dissolved in one litre of solution. To make such a solution, one would weigh out 100g and dissolve this in slightly less than one litre of water. To facilitate the dissolving of the soda it would be best to use warm water.

Once the solution is fully dissolved, or at least is dissolved as it can be (since not all the material may dissolve), water can be added to bring the solution to one litre.

If you do not have a method of directly measuring one litre you can determine the volume of 1 litre by pouring 1 kg of water (1 litre) into a container and marking the level on the side of the container. This will then be your 1 litre measuring vessel.

(Note that this procedure is NOT the same as just adding 1 litre of water to 100 grams of the soda, a common mistake).

You must use protective gloves and eyewear when making and using the solution as, although washing soda is a household chemical, it is still alkaline and possibly harmful to the eyes.

The power supply

A 12V car battery charger is commonly used for this process but this doesn't allow any form of current/voltage control. For a little more convenience you could use an adjustable bench power supply.

A standard car battery charger is sometimes used but has the disadvantage that very high currents may be drawn due to the highly conducting nature of the electrolyte solution.

High currents may be too high for the de-rusting process and further, these chargers may not be designed to have high currents drawn for the long periods of time this process may take. For these reasons, we do not recommend the use of a car battery charger for this process.

Correct polarity is VITAL!

We can't repeat this too many times:

POSITIVE goes to sacrificial anode.
NEGATIVE goes to item to be restored.

It is critical that you get the polarity correct, otherwise the object under restoration *will be dissolved!*

Always test your set up with a non-valuable piece first.

REQUIRED MATERIALS

A plastic bucket or container large enough to contain the item(s) to be restored.

A sacrificial anode made of uncoated mild steel which preferably surrounds the part to be restored. Graphite or platinum is also suitable but platinum is extremely expensive.

Washing soda powder (sodium carbonate) *as distinct from baking soda*. A 1kg packet costs around $4 in supermarkets. A popular brand is Lectric. What is not used will not be wasted as there are numerous household uses for this chemical (see manufacturer's website). This chemical can also be purchased as swimming pool pH increaser (to make the water more alkaline and less acidic) for about $10 for 2.5kg.

A power supply capable of at least 12V (up to 20V or so is better) and ideally up to 2 or 3A capacity, although lower capacity will suffice. It is preferable that the supply have a variable output voltage, as is the capability to measure voltage and current. The power supply used for this article was a Manson NP-9615 with an output of 0 to 30V at 5A and built in current and voltage meters but a much less capable supply will be suitable. A car battery charger is used by some people but is not recommended.

Two polarised leads with clips (ie, red and black) to connect the power supply to the electrodes.

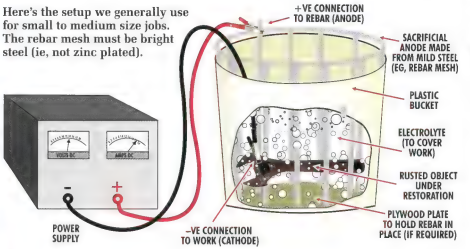
Rubber gloves and **safety glasses**.

Scales with which to weigh out the required amount of washing soda.

A way to measure the volume of water (or weigh it – remember that one litre of water weighs one kilogram).

And last of all . . . the rusty part(s) to be restored!

Here's the setup we generally use for small to medium size jobs. The rebar mesh must be bright steel (ie, not zinc plated).



The procedure

1. To start, choose an appropriate size plastic vessel (such as a water bucket) and install in it an uncoated mild steel sacrificial anode.
2. Make up a 5 or 10% weight-by-volume solution of electrolyte as described above and pour into the container. Normally you would want to ensure there is enough to cover the object to be restored but in some cases it might only be necessary to treat part of an object, so the part not needing treatment can be above the solution.

   Some people have reported success with much less concentrated solutions such as 'a (US) tablespoon to a (US) gallon of water'. You may wish to try lower concentrations to see if that works with the particular artefacts that you want to restore.

   The actual concentration is not likely to be critical, as long as the amount of electrolyte makes the water conduct electricity well.

   Note also that any paint on an object will likely be damaged or even removed by this process as the solution softens it. Any paint remnants can be removed with paint remover if desired or even before treatment if the paint layer is particularly robust.
3. Make sure loose dirt and rust is brushed off from the item to be restored and that any oil or grease is removed with a degreaser.
4. Attach the positive wire to the sacrificial anode and the negative wire to the work piece (ie, the rusty piece being restored).

   The clip attached to the work piece will not be significantly damaged but the one attached to the sacrificial anode will likely dissolve if it is not connected above the electrolyte level.
5. The item to be restored is placed in the cell and the power supply turned on to about 12 volts. Gas evolution should be noticed on both the sacrificial anode and the item under restoration – the time for this to happen depends a lot on the voltage/current applied.
6. Periodically, items should be removed and examined. Turn the power supply off before removing the item as sparks could ignite gases present.

   Each time an object is removed from the solution (wear rubber gloves and safety eyeglasses) it should be washed under cold water and loose rust brushed off with a nylon or brass brush. A sharp instrument may be needed to get material out of crevices.

Notes

- This article primarily refers to rust on mild steel and other low alloy steels only and was not tested or intended to be used on stainless steel (some grades of which do rust) or other metals such as copper, brass and aluminium.

  If you want to use this process on other materials, do your own tests. The amount of time the process takes depends on many factors but can take as little as tens of minutes to many hours or even days for heavily rusted items with deep recesses, such as nuts on bolts.
- When an item is removed and replaced it is important that the position of the electrode clip is moved

Providing a drill bit is still in reasonable state (ie, not too rusted or flaking), it can be restored to working condition.

and also that the restoration object is placed in a variety of positions to ensure all areas are treated and none are shielded.

- As red rust is electrically insulating the number of bubble sites on heavily rusted items may be relatively few at first. However, since red rust is also porous, as the electrolyte penetrates to the more conducting layers gas evolution will start to occur. The bubbles expanding within the porous red rust help to remove it. For very heavily rusted items it was found that the current and number of bubbling sites increased and then eventually the current decreased as the process moved to completion.
- Sometimes, on heavily rusted objects, no significant gas evolution would happen for a long time. It was found that the process could be facilitated by increasing the voltage to a point that gas evolution became apparent.

  After a while the voltage could be reduced but gas evolution would continue, as the impediment to current flow had been cleared.
- There is a critical voltage at which the appropriate electrochemical reactions occur. But without using a special reference electrode such as a 'standard hydrogen electrode' (SHE) this voltage needs to be guessed.

  It is the point at which significant gas evolution occurs and the current starts to increase rapidly. The voltage should not be set so high that there is extremely vigorous gas evolution. Generally 12V is enough but as mentioned above, it is sometimes advantageous to go beyond this in order to get the process started more quickly if there is a high initial resistance.

  (A DC voltage of 12 to around 30 volts is more than adequate for any conceivable cleaning operation).
- **NEVER attempt to connect to mains voltage – (a) it would be extremely dangerous and (b) being AC, it wouldn't work!**
- Concerning the optimal current to use (obtained by varying the voltage) it is not critical but it should be set to a level where there is a somewhat vigorous stream of bubbles coming from the artefact. In professional restoration of marine artefacts current densities in the range of anything from 0.001-0.1A per square centimetre of object area have been successfully used.
- Don't let the rusted item touch the sacrificial anode or you will short out the power supply.
- Make sure bubbles come from all areas on the part. With multipart objects a failure for bubbles to come from one part may indicate a lack of electrical connection between the parts. Applying another connection to such parts should rectify the problem.
- If the object has some type of "inert" plating such as chrome, as long as it is soundly attached, it should not generally be affected. However, if the plating is not sound it may be removed. Be sure to test a small part of the piece first, leaving most of the piece out of solution.
- Interestingly, it was noticed how, even with the power supply turned off a small voltage was present across the cell. This is because the materials are acting as a galvanic cell.
- The process is quite tolerant (except if the wrong electrical polarity is used!) and there will be no harm from leaving it run for too long a time. Good metal will not be adversely affected, however due to safety considerations the process should not be left unattended.
- Do not turn off the power and leave the item under restoration in the electrolyte solution for an extended length of time as it will start to rust again. Whilst a current is flowing the object will not rust (as long as there is sacrificial anode still present).
- To give maximum coverage it is best to suspend the articles in the solution.
- Multiple parts can be done at once with multiple parallel electrical connections.
- If you have a really large object to clean, be creative with your choice of container, eg, kids' inflatable swimming pools (but don't repurpose for use by kids after the job!), or dig a hole in the ground and line with plastic etc.

After the process has finished

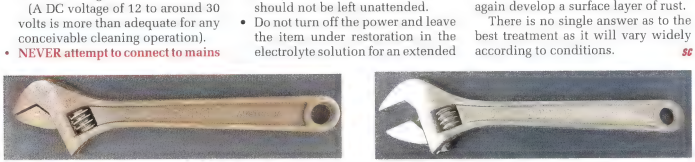
The process may be regarded as complete at the point that no more rust can be brushed from the object and the current generally drops to a much lower level than at its peak and also remains steady.

After the process is complete, remove the item (turn the power supply off first) and brush it rigorously with a plastic or brass brush under running water.

Use rubber gloves and safety eyewear. It should then be immediately sprayed or soaked in methylated spirits (warning – flammable) to remove residual moisture. Methylated spirits should then be wiped off so that none remains and then the item should be put near a source of heat such as a blow heater or hair dryer to thoroughly dry it.

After thorough drying the item can then be treated as required. It could be sprayed with a moisture displacing oil such as WD40 and regularly recoated, for example, or primed and painted or just left the way it is although it will again develop a surface layer of rust.

There is no single answer as to the best treatment as it will vary widely according to conditions. **SC**



Similarly, this "shifter" (which wouldn't shift – it was rusted closed!) is now bright, shiny . . . and completely usable!

Courtesy LED Lights Delay For Cars

Most modern cars have a courtesy light delay but older vehicles do not. This new circuit is specifically designed to suit LED lamps but will also work with conventional filament lamps. It keeps the interior lights of your car lit for a preset time after you shut the car doors. The lights will also turn off if the exterior lights or ignition are switched on during the time-out period.

IF YOU BUILD this courtesy light delay unit, you will be able to upgrade your vehicle to LED interior lighting (see SILICON CHIP, December 2013). LEDs give much improved lighting compared to the yellow of incandescent lamps and the bulb diffusers will not discolour with age.

We previously published a Courtesy Lights Delay unit in June 2004 and this has proved surprisingly popular. And while that project is still fine for 12V filament bulbs, it won't work with LED lighting unless you have at least one filament bulb connected; not the best compromise.

Just why our previous Courtesy Light Delay from 2004 doesn't work with LEDs can be understood by looking at Fig.1 which shows the earlier design concept. It's based on a Mosfet (Q1), two capacitors (C1 & C2) and a 1MΩ discharge resistor. When the door switch is closed, the interior lamp(s) light and the capacitors are discharged. The instant the door switch opens, the two capacitors charge via the filaments in the interior lighting.

Due to the different values of the two series-connected capacitors, the 47μF capacitor (C2) will charge to a voltage that's about 10 times higher than the voltage across the 470μF capacitor (C1). So with a 12V supply and taking into account the 0.7V drop across diode D1, the 47μF capacitor will have about 10.2V across it and the 470μF capacitor about 1.02V. The 10.2V across C2 becomes the gate voltage for the Mosfet which then drives the lamps. After a short time, the gate voltage discharges via the 1MΩ resistor and the lamps go off.

As shown in Fig.1, a few refinements were also included. These include adding a short time delay to prevent Mosfet Q1 from switching on instantly when the door switch opens. This is to allow time for capacitors C1 & C2 to charge sufficiently before the Mosfet switches on and shunts the door switch. This delay is achieved using transistor Q2, which is momentarily switched on at power-up (ie, when the door switch opens) due to base drive through the 100nF capacitor and 10kΩ resistor.

When Q2 switches on, it momentarily shunts Q1's gate to ground. This prevents Q1 from conducting until the 100nF capacitor charges. The duration is only 1ms and any tendency for the lamp to briefly flicker off as the door switch opens is virtually unnoticeable.

The full circuit published in June 2004 also included additional circuitry to switch off the Mosfet (and thus turn the interior lamps off) if the tail lights were activated (ie, if the parking lights or headlights were switched on).

As stated, this circuit doesn't work with LED lighting. That's because the circuit relies on current flowing through the lamp filaments, just after they are switched off, to charge capacitors C1 & C2. Typically, a 5W lamp filament will have a resistance of about 29Ω when it is hot and so the 47μF capacitor takes much less than 1ms to charge. However, interior lighting often uses more than one lamp and so the charging resistance is usually much lower than 29Ω.

By contrast, typical 12V LED lamps incorporate two or three white LEDs

Main Features

- Adjustable delay (1-133s)
- Works with both 12V LED lamps and incandescent/halogen filament lamps
- Low standby current drain
- Works with positive and negative door switch configurations
- Interior lamps go off when exterior lights or ignition are switched on

By JOHN CLARKE

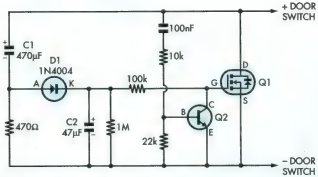


Fig.1: the basic design concept of our 2004 Courtesy Light Delay. It relied on current flowing through the lamp filaments to charge capacitors C1 & C2 immediately after the door switch opened.

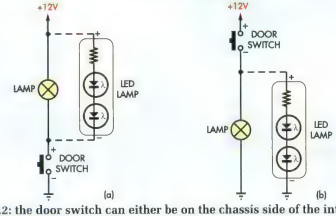


Fig.2: the door switch can either be on the chassis side of the interior lamp (a) or on the +12V side (b). Both the June 2004 circuit and the new circuit described here work with either configuration.

Other Uses

This PCB module is not just confined to vehicle use. Its circuit can also be used for timed lighting, such as in a hallway, provided you use 12V LEDs run from a 12V DC supply. A pushbutton momentary switch would be used to switch the lights on and they would then turn off automatically at the end of the preset period.

This would also be ideal for a stairwell with one or several pushbutton start switches (eg, one on each floor). With a 12V supply, up to 36W (3A) of lighting can be controlled and these could be powered from a 3A 12V power brick or similar (or use a 2A plugpack for up to 24W of lighting).

Note that the pushbutton switch needs to be rated for the total current drawn by the LED lighting.

connected in series with a current-limiting resistor. The voltage drop across each LED is typically 3.5V for a white LED and so the total voltage drop is around 7V with two in series or about 10.5V with three in series. So there is not much left of the 12V supply to charge the capacitors shown in Fig.1.

When twin-LED lamps are used in this circuit, the resulting gate voltage will be around 2.9V when using a standard diode for D1 and 3.13V when using a Schottky diode. We do not get the expected 3.8V because of the voltage drop across the current-limiting resistor in the LED lamp.

Now 3.13V is too low to fully switch on most Mosfets, including typical logic level types that can conduct (at least partially) with a 3V gate-to-source voltage but switch off below 2.5V. This means that LED lamps will not be correctly switched on by the circuit of Fig.1. Even if we substitute a Mosfet with a very low on-threshold voltage, it would be difficult to get a consistent delay period due to the low capacitor voltages compared to this threshold.

It's unfortunate that this circuit doesn't work with LED lighting because it has several desirable features. First, there's no need to connect it directly to the vehicle's 12V supply; you just connect across a door switch (in a vehicle with incandescent interior lamps) and it works. In addition, the circuit will operate regardless as to whether the door switch is on the negative side of the lamp (Fig.2a) or the positive side (Fig.2b). Provided it's connected with the correct polarity across the door switch, the circuit works in exactly the same manner for both 'high side' and 'low side' switching.

So how do we design a circuit to operate with LEDs? In this case, we need to connect our new circuit directly to the 12V supply as well as to a door switch. And if we want the interior lamps to switch off when the parking lights or ignition are turned on, then these too need to be monitored by the circuit.

LED version

Our new Courtesy LED Lights Delay circuit is shown in Fig.3. Unlike the June 2004 circuit, it also monitors the ignition as well as the exterior lights. Monitoring the parking lights or tail lights is only useful for night-time driving, since you are unlikely to use the lights during the day. By monitoring the ignition line, the courtesy lamps will immediately go out if the car is started rather than having to wait for the delay period to expire.

As with our previous circuit, the Courtesy LED Lights Delay operates with the door switch in either configuration (ie, high-side or low-side). Again, it's only necessary to wire the circuit to a door switch with the correct polarity. It's not necessary to know how the door switch is connected in the vehicle; you just have to identify its positive and negative leads.

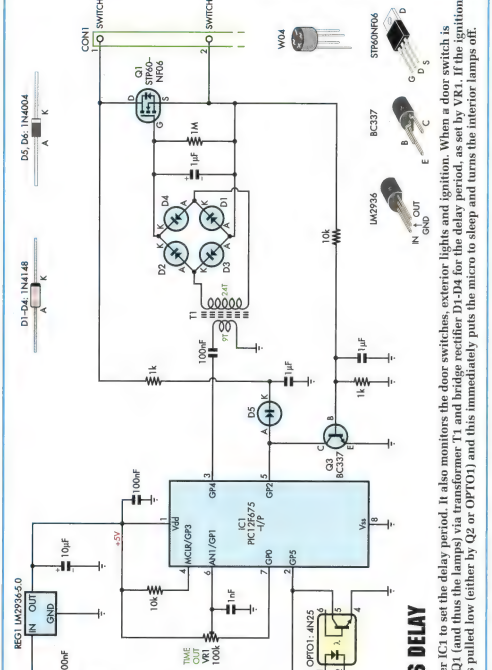


Fig.3: the circuit uses PIC microcontroller IC1 to set the delay period. It also monitors the door switches, exterior lights and ignition. When a door switch is opened, IC1's GP4 output drives Mosfet Q1 (and thus the lamps) via transformer T1 and bridge rectifier D1-D4 for the delay period, as set by VR1. If the ignition or exterior lights are switched on, GP5 is pulled low (either by Q2 or OPTO1) and this immediately puts the micro to sleep and turns the interior lamps off.

The other connections to the circuit are to +12V, chassis (0V), ignition and the switched supply for the vehicle's exterior lights. The lights connection can be regarded as optional; in many cases, it will be sufficient to simply monitor the ignition line to automatically turn the interior lamps off before the delay period has ended (ie, when the car is started).

The lights input connects across the parking lights or tail lights (but not the stop lights) and can be connected with either polarity.

If the courtesy lights use a low-side switching arrangement, Mosfet Q1's source terminal will be connected to ground via SWITCH-. But this won't be the case with high-side switching.

You might expect that this could be solved by driving Q1 with an IR2125 (or similar) Mosfet driver which could produce a suitable gate drive above the Mosfet's source voltage, whether that rises to the 12V supply (for a high-side connected Mosfet) or 0V (for a low-side connected Mosfet).

However, in the high-side configuration, this scheme relies on a low-impedance source load such as a light bulb to charge the boost capacitor during the Mosfet's off-time. This capacitor is subsequently used to generate a voltage above the 12V supply when the Mosfet switches on, so that it remains in conduction.

Once again, using LEDs for the load will mean that the capacitor will only charge to 12V minus the voltage drop of the LEDs. Ultimately, we would still be restricted to only a couple of volts for the Mosfet gate supply, so it won't work for the same reasons outlined earlier. Another problem is that the IR2125's quiescent current is rather high, at up to 1.2mA.

To get around this problem, our circuit is based on a PIC12F675-I/P microcontroller (IC1) and this drives Mosfet (Q1) via transformer T1. IC1 produces a 1MHz square-wave to drive the transformer and it provides a timing function to switch off this signal after a set period (the delay). This delay period can be adjusted using trimpot VR1.

In operation, microcontroller IC1 detects when a door switch is opened to start the delay period. It also monitors when the ignition or lights are switched on to cancel the delay period.

Because the circuit is always connected to the vehicle's 12V battery,

Specifications

Delay period: adjustable from 1-133 seconds
Dim down period: 1s (can be extended by changing 1µF gate capacitor on Q1)
Quiescent current: 17µA maximum, 9µA typical, 7.6µA measured (sleep mode, lamp off)
Current when running: 36mA plus LED lamp current

it's vital that microcontroller IC1 has a low quiescent supply current. As a result, IC1 is normally in 'sleep' mode and draws negligible current (up to 2µA maximum). In fact, most of the quiescent current is drawn by 3-terminal regulator REG1, as described later.

IC1's GP2 input indirectly monitors the door switch which is wired across the Mosfet. As shown, Q1's drain connects to the positive side of the switch, while its source connects to the negative terminal.

GP2 is normally held high via an internal pull-up resistor. When the door switch is in the ground side (see Fig.2a), a closed switch pulls GP2 low via a 1kΩ resistor and diode D5. At the same time, transistor Q3 will be off since Q1's source is at ground and so Q3's base is held at 0V.

Alternatively, if the door switch is connected in the positive side of the supply as in Fig.2b, a closed switch drives Q3's base via a 10kΩ resistor. As a result, Q3 turns on and pulls GP2 low. In this case, diode D5 is reverse biased as Q1's drain is connected to the positive supply.

So, for either connection of the door switch, IC1's GP2 input is high when the switch is open and goes low when the switch closes. IC1 is configured to generate an interrupt on a positive edge at input GP2 and when the door switch subsequently opens again, this interrupt wakes IC1 from its sleep mode. The microcontroller's firmware then starts an internal oscillator and this produces a 1MHz clock output at pin 3. This then drives transformer T1 via a 100nF capacitor.

Diodes D1-D4 rectify the voltage from T1's secondary and the resulting DC is filtered by a 1µF capacitor. This in turn switches on Mosfet Q1 to drive the interior lights, just as if a door switch was closed. Note that D1-D4 are 1N4148s since a standard bridge rectifier would not work at 1MHz.

The end result is that Q1's gate is charged sufficiently above its source to ensure it switches on, regardless of whether the source voltage is actually 0V or 12V. This configuration is known as a 'floating gate supply'.

At the same time as Q1 is switched on, IC1's GP0 output is taken low (to 0V) and this connects a 5V supply across trimpot VR1 (100kΩ). The setting at VR1's wiper is then read via IC1's AN1 input. The GP0 output is then taken high to stop the current flowing through VR1 and this is done to minimise the current drain, particularly during sleep mode.

IC1 goes to sleep again at the end of the time-out period, as set by VR1. This stops the 1MHz drive to transformer T1 and Mosfet Q1 then quickly dims the interior lights over a nominal one second period as its 1µF gate capacitor discharges via a parallel 1MΩ resistor. Basically, the Mosfet's internal impedances rises in response to decreasing gate voltage, thereby dimming the lights until they are ultimately completely off.

Interrupting the delay

IC1 monitors the ignition and taillights circuits via its GP5 input at pin 2. If either the ignition or lights are switched on during the time-out period, the PIC immediately goes to sleep and the interior lights go out.

In greater detail, GP5 is normally held high via an internal pull-up resistor. If the ignition is switched on (eg, when the car is started), it drives the base of Q2 via a 10kΩ resistor. Q2 thus turns on and pulls GP5 (pin 2) of IC1 low to put the micro to sleep.

Alternatively, if the external lights are switched on, the resulting 12V DC supply is fed through bridge rectifier BR1 and drives the LED in optocoupler OPTO1. This in turn switches on OPTO1's output transistor, again pulling GP5 (pin 2) of IC1 low and putting the micro to sleep.

BR1 and optocoupler OPTO1 ensure that the lights circuit will work regardless of how they are switched in the vehicle. It doesn't matter whether the lights are ground connected and switched to positive or connected to positive and switched to ground.

Power supply

Power for the PIC microcontroller is derived from the vehicle's 12V supply

Parts List

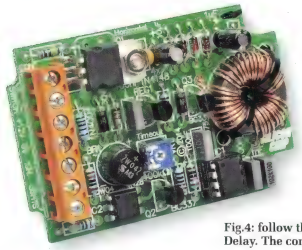
1 double-sided PCB, code 15109141, 71 x 47mm
1 UB5 jiffy box, 83 x 54 x 31mm
1 panel-mount cable gland for 6.5mm diameter cable
1 ferrite toroid ring core, L8 material, 18mm OD, 10mm ID, 6mm high (Jaycar LO-1230)
1 8-pin DIL IC socket
1 3-way PCB-mount screw terminal block (5.08mm spacing) (CON1)
2 2-way PCB-mount screw terminal blocks (5.08mm spacing) (CON1)
1 M3 x 6mm tapped Nylon spacer
1 M3 x 12mm machine screw
1 M3 nut
2 100mm cable ties
1 700mm length of 0.8mm enamelled copper wire
1 100kΩ miniature horizontal trimpot (VR1)

Semiconductors
1 PIC12F675-I/P microcontroller programmed with 1510914A.hex (IC1)
1 4N25 or 4N28 optocoupler (OPTO1)
1 LM2936-5.0 low dropout 5V regulator (REG1)
1 STP60NF06 60V N-channel Mosfet or similar (Q1)
2 BC337 NPN transistors (Q2,Q3)
1 W04 400V 1.2A bridge rectifier (BR1)
4 1N4148 diodes (D1-D4)
2 1N4004 1A diodes (D5,D6)
1 30V 1W zener diode (ZD1)

Capacitors
1 10µF 16V electrolytic
1 1µF 16V electrolytic
2 1µF monolithic multi-layer ceramic
3 100nF MKT (code 100n or 104)
1 1nF MKT (code 1n or 102)

Resistors (0.25W, 1%)
1 1MΩ
2 10kΩ
1 4.7kΩ
3 1kΩ
1 100Ω

Miscellaneous
Automotive wire, crimp connectors, quick splice connectors



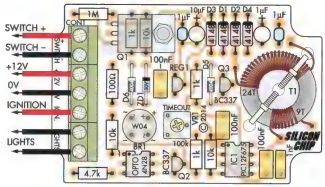


Fig.4: follow this diagram and the photo at left to build the Courtesy LED Lights Delay. The connection to the exterior lights circuit is optional.

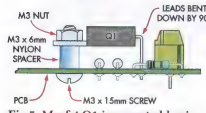


Fig.5: Mosfet Q1 is mounted horizontally, with its tab secured to an M3 x 6mm Nylon spacer.

Be sure to feed the M3 x 15mm screw that secures Q1's tab to the spacer up through the bottom of the PCB.

via an LM2936 5V automotive regulator (REG1). This regulator can handle a reversed supply input and has voltage transient clamping. Diode D6, zener diode ZD1 and the 100Ω resistor are included to add extra protection. The overall quiescent current of the circuit is very low at around 9µA typical and is mainly due to the minimum current drawn by REG1.

Software

Not much is required in the way of software for IC1. As stated, it includes a rising edge interrupt handler that wakes the PIC from sleep whenever a door switch is opened from its closed position. The PIC's internal oscillator is then automatically started and it generates the 1MHz clock signal at pin 3.

The delay counter is set from 1-133s, depending on the 8-bit ADC reading from AN1 and this period is timed using the overflow period of the internal 16-bit timer (timer 1), which occurs every 524ms.

When the delay counter reaches zero, the PIC is placed back into sleep mode so that it draws minimal power and the 1MHz clock signal ceases. During the delay period, the GP5 input is monitored and if this goes low, the processor is immediately placed in sleep mode and the LED lights quickly dim to off.

Construction

The Courtesy LED Lights Delay is built on a double-sided PCB coded 15109141 and measuring 71 x 47mm. This clips neatly into the side channels of a UB5 plastic case and there is sufficient room to install a cable gland at the terminal block end.

Fig.4 shows the parts layout on the PCB. Install the resistors first, followed by diodes D1-D6 and zener diode ZD1. Check each resistor with a multimeter before soldering it in position and make sure that the diodes and zener diode go in with the correct polarity. The zener diode is a 30V type and will probably be marked as a 1N4751.

OPTO1, the 4N25 optocoupler, is installed next, along with an 8-pin DIL socket for IC1. Be sure to orientate these parts as shown on the overlay (ie, pin 1 at top left). Transistors Q2 & Q3, regulator REG1 and bridge rectifier BR1 can now go in. Check that the LM2950-5.0 device goes in the REG1 position and check that BR1 is correctly orientated and sits flush against the PCB before soldering its leads.

The capacitors are next on the list. Watch the orientation of the electrolytics and make sure that their tops are no more than 12.5mm above the PCB, otherwise they will later foul the lid of the case. The parts list shows the codes used for the 100nF and 1nF capacitors.

Connector CON1 is made up using one 3-way and two 2-way screw terminal blocks. These should be dovetailed together to form a 7-way block which is then mounted on the PCB with the wire entry holes facing towards the adjacent edge. Make sure that this 7-way connector sits flush against the PCB before soldering the pins.

Mosfet Q1 is mounted horizontally on the PCB with its metal tab secured to an M3 x 6mm Nylon spacer. To do this, first bend the Mosfet's leads down through 90° about 1mm from its body,

Table 1: Resistor Colour Codes

❑	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	1	1MΩ	brown black green brown	brown black black yellow brown
❑	2	10kΩ	brown black orange brown	brown black black red brown
❑	1	4.7kΩ	yellow violet red brown	yellow violet black brown brown
❑	3	1kΩ	brown black red brown	brown black black brown brown
❑	1	100Ω	brown black brown brown	brown black black black brown

then fit the Mosfet in position and slide the Nylon spacer into position under its tab. The assembly is then secured to the PCB using a M3 x 12mm screw and nut – see Fig.5.

Note that this screw must be inserted from the underside of the PCB, so that the nut goes on top of Q1's tab. That's because the screw head is small enough not to foul adjacent PCB tracks, whereas the larger nut would run the risk of shorting out an adjacent 1µF capacitor. Do the screw up firmly to secure the assembly, then solder the Mosfet's leads to the PCB.

Winding T1

The PCB assembly can now be completed by winding and installing transformer T1. This transformer consists of two windings on a ferrite ring core, as shown in Fig.4. The first winding consists of nine turns of the 0.8mm enamelled copper wire, while the second consists of 24 turns of 0.8mm enamelled copper wire. They are wound on opposite sections of the core and it doesn't matter in which direction they are wound.

Once the windings are in place, position the toroid on the PCB. The 9-turn winding goes through pads at the lower righthand side of the PCB, while the 24-turn winding goes to a pad just to the right of Q3 and to a pad at top right. Push the toroid all the way down onto the PCB, the secure it in position using a couple of cable ties. These pass through the centre hole of the toroid and through adjacent holes on either side.

Note that the enamel coating will need to be scraped off the wires before soldering them to the PCB.

Testing

Before installing the PIC micro, connect a 12V supply to CON1 and check that there is about 5V (4.85-5.15V) between pins 1 and 4 of IC1's socket. If this voltage is correct, disconnect the power and install IC1 with its pin 1 to the top left. If the voltage is incorrect, check the orientation of D6, the value of the series 100Ω resistor and that REG1 is an LM2936-5.0.

If you have a spare 12V LED lamp, this can be used to test the circuit before installing it in the vehicle. **Do not use a white LED on its own. It must be a LED lamp with a limiting resistor to keep the current to a safe level for the LEDs.**

Assuming you have a spare LED lamp, connect it between the switch minus terminal (pin 2 of CON1) and 0V (pin 4 of CON1). **Note that the polarity is important here – the anode or positive side of the LED lamp must go to the switch minus terminal.**

Now reapply power – the LED lamp should light for a second or so, then quickly dim to off. If that checks out, momentarily bridge the switch terminals on CON1 (pins 1 & 2). The LED lamp should now light for the length of time set by trimpot VR1 (note: timing begins when the door switch opens; ie, when the door is closed).

Assuming it works as expected, VR1 can now be adjusted to set the required delay. This ranges from 1-133s but note that the circuit's response to the trimpot setting is non-linear. The fully anticlockwise to mid-position setting has the range of 1-33s, while the next half of the travel is divided into two equal sections. The first section has a range from 33-66s, while the remaining clockwise section sets the delay from 66-133s.

Having set the delay period, you can test that the ignition input works. That's done by first triggering the delay period, then connecting the ignition input (pin 5 of CON1) to +12V using a wire link. When you do this, the lamp should extinguish after one second or so.

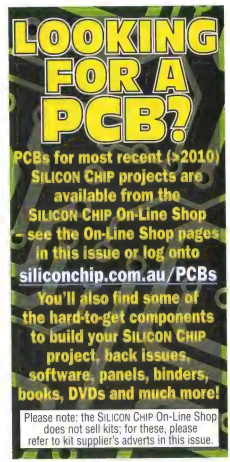
Note that you will need to set a reasonably long delay time for this test, to give yourself time to connect the ignition input to the +12V terminal.

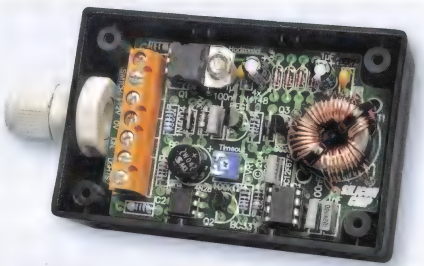
Similarly, you can check that the lights inputs work by triggering the delay and connecting either pin 6 or pin 7 of CON1 to +12V and the other pin to ground. Again, the LED lamp should turn off after a second or so.

If you wish, you can increase this 1s dim-down period by increasing the 1µF electrolytic capacitor value at the Q1 gate. It will be around 10s with a 10µF capacitor. Note that this dimming period is additional to the time-out or delay period. So if the time-out is set at 15s, the overall LED 'on-period' will be 15s plus the dimming period. For 1s dimming, the total time-out will be 16s.

Final assembly

If it all works as expected, drill a 12.5mm hole in the end of the UB5 box for the cable gland. This hole should be positioned 13mm down from the top





This is the view inside the completed Courtesy LED Light Delay. It's best to make the external wiring connections to CON1 with the PCB out of the case. The wires are then pushed back out through the cable clamp as the PCB is clipped into position.

of the box and centred horizontally. Drill a small pilot hole to begin with, then carefully enlarge it to size using a tapered reamer and mount the cable gland in position.

The assembled PCB is now simply clipped into the UB5 box with CON1 adjacent to the cable gland. This gland clamps the external wiring cable to prevent the connecting wires from being pulled out of CON1.

Installation

To connect the unit, you will need to access one of the door switches, +12V power, the ignition line and either the tail light or parking light connections. Alternatively, you may wish to just use the ignition input and not bother with the lights input.

Note that some door switches will have two wires while others have only a single wire connection. In the latter case, one contact is connected directly to chassis at the switch mounting position.

It's important to get the door switch connections to the unit the right way around. The positive door switch connection must go to the switch positive of the Courtesy LED Light Delay. You can quickly determine which is the positive door switch connection by using a multimeter to measure the voltage across the door switch when it is pushed open.

Note that if there's only a single wire running to the switch, this will be the positive (assuming the chassis connection is negative).

For the +12V supply rail, you will need to find a source of +12V that remains on when the ignition is off. This +12V supply rail must be protected by a fuse in the vehicle's fusebox and is best derived at the fusebox itself. The 0V lead can be run to an eyelet connector that's screwed to the chassis.

The lights terminals on the Courtesy LED Lights Delay are connected across one of the tail lights or parking lights. You can access this wiring either directly at the lights socket wiring, at the lights switch or in the fusebox. It doesn't matter which way around you connect them, since the bridge rectifier automatically caters for both polarities.

Once you have found the relevant wiring points, it's a good idea to disconnect the vehicle's battery before running the wiring, to guard against any inadvertent short circuits. Note that all wiring should be run using proper automotive cable and connectors.

Once the wiring is complete, reconnect the battery and check that the courtesy lights remain on after the door is closed. Now turn the ignition (or the exterior lights) on and the courtesy lights should quickly dim to off (over 1s or so).

Finally, the unit can be mounted in any convenient location under the dashboard. It's up to you how you secure it, since a suitable position will vary from vehicle to vehicle.

Existing delay circuit

What if your vehicle already has a courtesy lights delay? This may work fine if you substitute LED interior lamps for your car's original incandescent lamps but there's always a possibility that it may not. In that case, you may wish to use the SILICON CHIP Courtesy LED Lights Delay instead.

One problem here is that the door switches will probably be connected to the existing delay circuit rather than directly to the interior lamps. Bypassing this delay circuit will therefore involve disconnecting all the door switches and wiring them directly to the interior lamps instead.

That's too complicated (and time consuming) to be practical in most cases but there is a way around this – keep the original delay circuit and simply add the SILICON CHIP Courtesy LED Lights Delay unit to the existing installation. That's done by connecting the SILICON CHIP delay unit in parallel with the existing unit across one of the door switches.

There's just one wrinkle to watch out for here – the original delay circuit may pull one side of the door switch to +5V rather than +12V. This should be checked using a multimeter and if it does go to +5V, the 1kΩ pull-down resistor connected to Q3's base will have to be increased to 10kΩ (otherwise the transistor won't turn on).

Note that, depending on the circuit used, the original delay period may be added to the delay introduced by the SILICON CHIP unit. That won't be a problem, however, since the Courtesy LED Lights Delay period can be adjusted down to as low as 1s.

Note also that connecting the Courtesy LED Lights Delay in parallel with an existing delay circuit may not work in all cases. It will very much depend on the vehicle and the circuit used.

Troubleshooting

If the courtesy lights are always on, the door switch terminals have probably been connected to CON1 (at pins 1 & 2) with reverse polarity. If that happens, the courtesy lights turn on via the intrinsic reverse diode inside Mosfet Q1 and simply swapping the leads to the door switch will fix the problem.

Finally, if the interior lights switch off immediately after the door is closed (and the connections are correct), check that there is no voltage applied to either the lights terminals or the ignition terminal on CON1 (pin 5, 6 & 7). SC

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SERVICEMAN'S LOG

Sometimes you just have to give it a go

Dave Thompson*

In this game, it's important to try to stay up-to-date with technology but we cannot know everything about everything. Sometimes, when there's nothing to lose, we just have to bite the bullet and give it a go, even though we might be learning on the job.

PEOPLE SAY that a change is as good as a holiday, though this usually seems to be more an attempt at consolation than a fair trade. Forget the change; I'd much rather the holiday!

That said, change is a big part of life and some people cope better than others. Getting older is one change we all have to deal with and while some welcome the prospect of slowing down and aging gracefully, others baulk at the idea and try everything they can to keep the wrinkles at bay.

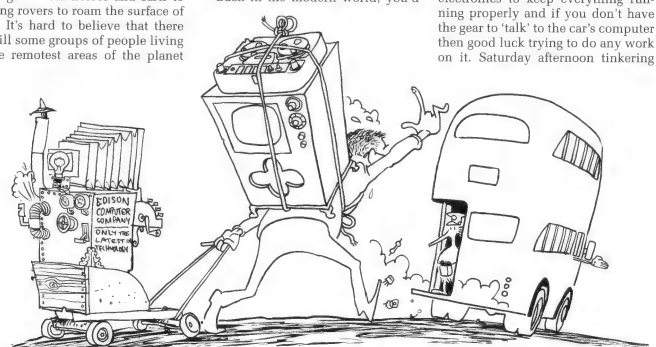
Of course, some of the most obvious changes we've seen are in the field of technology. In our collective lifetimes, we've gone from horses and carts to sending rovers to roam the surface of Mars. It's hard to believe that there are still some groups of people living in the remotest areas of the planet who don't have access to electricity, let alone radio, TV or mobile phones.

Then again, perhaps it's not so hard to believe when you consider that it was only 100 or so years ago that the machine age was really getting into gear (pun intended!), with rapid advances in automation, communications and transport. With necessity being the mother of invention, many of these technological improvements were developed during times of global unrest and put to use with devastating effect during the two world wars. Technology really can be a double-edged sword.

Back in the modern world, you'd think servicemen would embrace change and relish the challenges of keeping up to date. However, while some nearing retirement might still be excited at the prospect of new technical advances, others simply give up learning or can't be bothered keeping up with current trends.

For my part, I'd like to think that most servicemen find learning new skills and gathering knowledge stimulating and a reason to get out of bed in the morning. But keeping up can be tough; I was recently speaking with a car mechanic and I wouldn't fancy being in that trade. The difference between cars today and cars of even 20 years ago is vast.

Gone are the days when backyard mechanics with just a socket set and two screw-drivers (one flat and one Phillips) could change their own points or tune their engine with a strobe light and dwell meter borrowed from a mate. Nowadays, cars are almost totally reliant on complex electronics to keep everything running properly and if you don't have the gear to 'talk' to the car's computer then good luck trying to do any work on it. Saturday afternoon tinkering



UNFORTUNATELY, IN OUR BUSINESS, ANY SERVICEMAN WHO DOESN'T MOVE WITH THE TIMES WILL SOON BE LEFT BEHIND

Items Covered This Month

- No-name tablet repair
- B&D CAD4 garage door controller
- Faulty solar panel inverter
- Burnt-out washing machine saves dishwasher
- HP LaserJet 1320N
- Motor start capacitor failure

Dave Thompson runs PC Anytime in Christchurch, NZ.
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is now almost a thing of the past; it's something our dads used to do but our kids likely never will.

In our business, any serviceman who doesn't move with the times will soon be left behind. For example, towards the end of 2012, Microsoft released Windows 8, the latest in their line of Windows operating systems. It's different enough from previous versions of Windows to alienate even some diehard Microsoft fans and many users have avoided it for that reason and delayed upgrading.

As a computer serviceman, I simply had to learn Windows 8 because that's my job. After all, I'm expected to know more about it than the person bringing in a computer to be fixed.

I'm also expected to know the quirks and the methodology behind repairing it when it goes wrong. In the same way, I expect my mechanic to be able to fix that new car I just bought or an appliance technician to be up to speed with the latest bubble-wash technology when my washing machine goes wrong. But here's the rub; I have to trust that these people have kept up. I certainly don't want them charging me top-dollar to learn on the job or to make things up as they go along.

In my case, it means that the person who brings me their latest Android-based tablet or shiny new Apple product expects me to know everything about it. As a result, I try my best to ensure that I know enough to at least keep out of trouble. After all, I need to be able to effectively repair these products in order to make a living.

At the same time, it's completely unrealistic to expect anyone to know everything about everything. What's more, as a responsible serviceman, I need to know my limits. If someone wants me to work on something I know little or nothing about I'll tell them straight that I'm not the best guy for this job. And where possible, I'll point them in the direction of someone who can do the work.

But that's me and I know that there are people out there prepared to fudge their way through without knowing what they are doing, just to make a few bucks. That's not only doing a great disservice to their client but a dodgy (or inadequate) repair can also reflect badly on the trade, giving the rest of us a bad name.

Sometimes though, there's no other option but to 'give it a go' if the gear is to be fixed. Of course, that's only done with the full agreement of the client. I also make it clear that I will be 'learning on the job' and will be doing the work at a cut rate, if not for nothing.

No name tablet

That's exactly the situation I was confronted with recently when a client called about a tablet that had stopped working. It did nothing when the power switch was pressed, so the first thing I assumed was that the charging socket was faulty and that the battery wasn't charging. My theory was that the battery was probably dead flat and unable to power the tablet up.

The big problem was that this was a no-name tablet, one of thousands now flooding the market on this side of the world and sold by the van-load from online auction sites. And with many running tweaked (read modified) versions of Google's Android operating system, repairing them can be a royal pain in the rear end. This isn't just because parts are nigh on impossible to get but because if the OS gets corrupted, finding and downloading the custom version of the Android system used can be almost impossible.

At one stage, I looked into selling no-name phones and tablets and while they do look shiny and alluring and have the right gadget appeal, the reality is that the build quality is often questionable. This makes them overly prone to failure and trying to obtain back-up service and support from the overseas vendor is about as easy as pulling your own teeth. Some of these devices might last a year (the standard factory warranty) but many don't. And when I tell clients that their device is non-repairable or that the repair will be expensive, most just shrug their shoulders and go out and buy another one to replace it.

~ PROVIDED I HAD HIS BLESSING

To me, this is 21st century consumerism at its worst; built-in obsolescence and a throw-away society equals mountains of dead electronic devices and massive pollution wherever it ends up. That's usually some 'recycling depot' placed deliberately out of sight somewhere in deepest Asia where crude foundries smelt whatever precious metals can be separated from the carcasses of our dead hardware and the plastics are burnt off into the atmosphere and end up as acid rain. There really has to be a better way.

OK, time to get off my hobby-horse; this particular tablet was dead and when I talked to the client, I immediately told him that I'd never fixed this type of unit before. I also told him that provided I had his blessing I'd take the back off, check out the charging system and if it was repairable, fix it for him. I'd also do this for a reduced fee because I'd be learning on the job and that was something he shouldn't have to pay full rates for.

I also warned him that if the problem was something deeper inside the tablet, such as a corrupted OS or faulty hardware, then it could prove non-repairable. In that case, he'd still be liable for the cost of my labour to determine this fact. He was OK with all that because, as he put it, he "had nothing to lose" by me having a crack at it.

As soon as he'd gone, I popped the back off the tablet, always a fraught

B&D CAD4 Garage Door Controller

A simple fault in one component was enough to bring a garage door controller to it knees, as G. I. of Castle Hill, NSW recently discovered. Here's what happened . . .

My friend Jan likes her creature comforts so you can imagine her frustration when her automatic garage door controller suddenly failed. This unit is a now-discontinued B&D CAD4 model controlling a one-piece tilt-a-door and had probably been installed during the late 1990s.

The unit had actually being showing a minor fault symptom for some time in that it would very occasionally fail to respond to both the remote control and the hard-wired button on the garage wall. However, it would always come good after several presses and so this was regarded as little more than a minor inconvenience.

Because it occurred so infrequently, the problem wasn't considered worth pursuing at the time. But now the unit had stopped completely, although relay "chatter" could occasionally be heard when the button was pressed. There were no sounds from the motor or drive mechanism though.

Curious as to what the problem might be, I volunteered to take a look at it. Because it had been a sudden failure, I reasoned that the fault probably lay in the control box. The drive mechanism hadn't shown any signs of trouble up until that point and Jan had already removed the bottom cover from the unit and inspected the Nylon drive-gear assembly, as well as the rest of the mechanism including the trolley and the chain drive.

These parts were all OK, so the likely suspects were a fault on the control PCB, a faulty motor-start capacitor or a faulty drive motor. Troubleshooting it in-situ wasn't practical, so Jan decided to take the control box down. That way, I could take it home and troubleshoot it on the workbench.

Getting the unit down was basically just a matter of disconnecting the chain, undoing the bolts that secure the trolley to the top of the unit and then unbolting the unit from its ceiling brackets. The unit was subsequently given to me the following weekend and I took it home and set it up on the workbench.

The B&D CAD4 (Control-A-Door) is a well-made unit and despite its age (and the work it had done), this one appeared to be in excellent condition. The bottom cover had been left off, so I placed the unit upside down on the bench and took a good look inside.

The control PCB sits vertically at the rear of the unit, behind a plastic panel which is in turn attached to a metal chassis. Immediately behind this is the Nylon gear-drive assembly, while an open/close limit-switch mechanism is attached to a metal bracket immediately above this assembly. The 230VAC motor is at the front of the unit, with its associated start capacitor adjacent to one side.

The wiring and gear mechanism all appeared to be OK, so I carefully straddled the unit across an open cardboard box and wired a push-button switch to the up/down contacts on the rear panel. I then plugged the unit into the mains, checked that the chain-drive sprocket was in the clear and pressed the button.

The result? – nothing; absolutely nothing. Pressing the up/down button several more times gave the same result, so it was time to take a look at the control PCB.

First, I unplugged the unit from the mains (important since mains voltages are present on some PCB tracks) and removed the rear panel and PCB assembly from the chassis by undoing several self-tapping screws. This then allowed me to undo several more screws at the back of the PCB, so that the board could be detached from the panel to reveal the component side.

I spotted the likely culprit almost

procedure due to the fact they are typically clipped on using plastic retaining clips and these are easily broken. The first time the back comes off, it certainly sounds like they are breaking as they let go but with the right spudger (prying tool), I can usually get things apart without any damage.

A trick for young players here is that many tablets have a couple of screws holding the back on, either conveniently hidden away among the various ports and sockets or hidden under thin plastic covers that need to be removed (I use the sharp tip of a craft knife for this task). Indeed, I've had several tablets brought in for repair over the years with cracks in the rear covers. In each case, some amateur repairer had tried to force the cover off, not realising that screws were holding it in place.

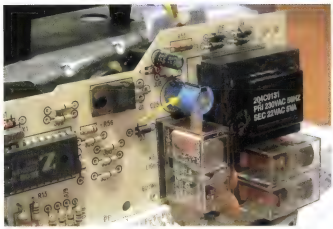
With the back off, it was an easy-enough task to check out the charging circuit. Most tablets use either a micro-USB connector or a standard 2.1mm DC connector, both of which regularly give up through too much tension being applied to the charging plug and/or cable. Fortunately, both sockets offer ready access to their PCB connections and by using a multimeter and some nice, sharp probes, you can quickly determine whether or not the charging circuit is still intact.

In this case, the socket was a DC type and with the power supply plugged into it, I could track and measure 5V all the way to the circuit board.

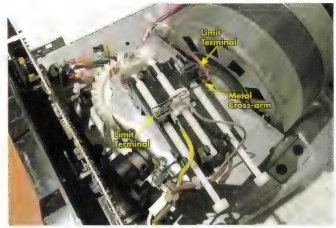
Another quick and dirty test of charger operation is to measure the voltage across the battery. Plugging and unplugging the power supply should see some variation in the battery voltage and given that the battery usually connects to the PCB using heavy gauge red and black wires (either soldered directly or via a slim-line Molex-style connector), the battery connections are usually easy to locate and access.

The actual voltage figure you get doesn't really matter and depends on the state of charge of the battery. However, when the power is plugged in, there should be a small gain in overall voltage and a corresponding drop when the power is removed. If so, that indicates that the charging circuit is working.

The battery these days is typically a lithium-polymer (LiPo) type. If it has failed, then you'll get somewhere in the region of 4-5V across its terminals



There are only two electrolytics on the control board and they're easy to replace. C25 (330µF 35V) was the culprit in this case and its replacement unit is shown arrowed.



The view inside the unit. When the motor runs, a central worm gear drives a metal cross-arm in one direction or the other, until it contacts one of the limit terminals.

straight away. There are only two electrolytic capacitors on the control board and one of them, a 330µF 35V unit (C25) adjacent to one of the relays, had a very slight bulge at the top. This capacitor appeared to be across a relay coil and if it was indeed faulty, it was possible that the relay wasn't being activated.

But was it going to be that easy? I whipped the capacitor out and soldered a new 470µF 50V unit in its place. While I was at it, I changed the other (smaller) electrolytic capacitor for good measure, even though it appeared to be OK. I then reassembled the unit, set it up with the exposed chain-drive sprocket clear of any obstructions and reconnected the power.

It was time for the smoke test. I pressed the open/close button and the motor immediately started and continued running until one of the limit switches closed. I then pressed the button again and the motor ran in the opposite direction until the other limit switch closed.

So yes, it was that easy and the replacement part cost less than $1.00.

All that remains now is to re-install the unit and there's a set procedure to be followed to ensure that the door operates reliably and safely. The CAD4 installation manual is on the B&D website and clearly describes the adjustment procedure.

Basically, the unit has to be installed so that the limit switches operate correctly at either end of the door travel. It's also necessary to tweak the force adjustment controls, so that the door easily stops and reverses if an obstruction is encountered in the downwards direction (or if it encounters a 40mm-high obstruction on the garage floor). Similarly, it should stop if an obstruction interferes with the door's upwards travel.

None of the adjustments has been interfered with on the repaired unit so it should simply be a matter of re-installing it to match the way it was, with only minor tweaking necessary afterwards. As for that faulty 330µF capacitor, it measured just a few nanofarads and had a very high ESR. It's a wonder that the unit kept working for as long as it did!

when the charger is connected but it won't retain any charge. Instead, the battery voltage will fall to zero (or below 3.7V) when the power supply/charger is removed.

If the battery has been allowed to sit without being charged for months on end, chances are it will not be in any fit state to be charged. And that's regardless of how much current you try to pump into it or how long you do it for. In fact, doing this can be extremely dangerous with LiPo batteries and, despite the temptation, you just shouldn't do it.

Those of us used to working with lead-acid and NiCd batteries have, on occasions, given them some serious 'beans' for a minute or two in order to 'shock' them into accepting charge. In some cases, this does work, though the I'd wager that the lifespan of the battery was usually shortened by this procedure.

If you do this with a LiPo battery though, you are courting disaster. Don't belive me? – there are enough examples of exploding batteries on the internet to provide a suitable deterrent to those who think their experience will somehow be different because their case is 'special' or they "know what they are doing".

Of course, if you want to see flaming battery gel splattered all over your workshop, then by all means carry on. On the other hand, if the battery measures 3V or below at full charge with no load, it's far better that you simply trust me when I tell you that it's ruined and beyond repair, no matter what some 'expert' on the internet claims.

In this case, I was getting just under 5V at the charging socket and the logic board, so the charging circuit was intact. The battery appeared to be taking a charge and holding it and that was a bother because it meant that something else was wrong and given the symptoms, it was possible the operating system had become corrupted.

Now this isn't necessarily as bad as it sounds; Android has several 'modes' you can use to try to repair the system or recover from a corrupted installation. You put Android into these modes by pressing a combination of the power, volume and other keys and once there you can perform tasks like installing updates, refreshing the system or even testing out individual components.

Obviously, you can break things

Washing Machine Saves Dishwasher

What's better than just having a smoke alarm? Having a smoke alarm AND two cats, according to J. C. of Moonbi, NSW, especially if your washing machine starts smoking. Here's his story . . .

In September 2012, I wrote about an Ariston KS2050A dishwasher that had overflowed into its drip tray and damaged the motor windings in the process. Fortunately, I was able to repair the machine but it has had another couple of mishaps since then.

The first problem was that the main power switch failed but that was easy to diagnose and fix. And the second? . . . well, one day after the dishwasher had finished its cycle, it still had litres of water remaining in the bottom. Clearly, the drain water pump wasn't pumping too well or the drain pipe had become clogged.

On inspection, I discovered that there was a leak inside the pump itself and this had allowed water to fill the cavity where the motor's rotor spins. This slowed it down considerably, so it no longer pumped the water out. We certainly don't seem to have much luck with appliances but this time, the dishwasher was saved by the almost simultaneous demise of a different appliance – our washing machine!

Previously, our washing machine (an Ariston AVXL129) had developed a problem whereby it would regularly stop working with its indicator LEDs flashing randomly at a fast rate. I reasoned that the problem would be in the main control board but was advised that a new one was over $500 so I decided to see if I could fix the problem myself.

The first step was to check the low-voltage power supply. I began by connecting a pair of wires across the supply rails and brought these out of the washing machine to make checking easier, especially when the machine stopped working. However, not having a circuit and being unfamiliar with the circuitry, I wasn't sure whether or not this low-voltage supply floated at mains potential.

To be on the safe side, I assumed that it did and so I fully insulated the wires and terminated them in a mains terminal block. This would allow me to safely insert the multimeter probes into this block to measure the low-voltage supply without fear of electrocution.

That measurement immediately revealed the fault. The supply was normally 5V DC but would intermittently drop to hover at less than half this. And that's when the machine stopped running and the LED lights flashed erratically.

Subsequent close examination of the PCB revealed that a TNY264P off-line switcher was the controller for the supply. I then checked the board with a magnifying glass and discovered that a surface-mount bypass capacitor for this device was only soldered on one side. It left the bypass pin (BP) open, resulting in the likelihood of erratic operation.

This joint was resoldered and the machine then performed flawlessly for several months. And then one night, the washing machine caught fire. This fire started in the main drive motor and had nothing to do with the earlier electronics repair. Instead, the main washing drum had developed a pinhole and this had allowed water to drip onto the motor, creating an electrical leakage path.

Our two cats sleep in the laundry and it was their loud yowls that woke us up. Understandably, they were desperate to get out by the time we reached them, as the smoke had almost reached ground level. The smoke alarm in the hallway just outside the laundry didn't sound until we opened the laundry door so if it hadn't been for the cats waking us, this story may well have had a different ending.

We immediately disconnected the power and put the fire out with a fire extinguisher. We then dragged the machine outside. This wasn't an easy task since the machine was quite hot after the fire and being full of wet towels and water, was decidedly heavy.

The next day, I checked the damage and it was obvious that it was a write-off. Very few parts were salvageable but one part I did salvage was the drain water pump.

Now, apart from the colour of the impeller and a few other cosmetic differences, this pump was identical to the one required for the dishwasher. What's more, a drain water pump for a washing machine does the same job as that in a dishwasher and both units were from the same manufacturer, so I decided to give it a try. It proved to be ideal and the dishwasher now runs completely through its cycle, fully draining out the water when required to do so.

So, in the interests of safety, it is recommended that you get a cat or a smoke alarm for your laundry. We have two cats and a smoke alarm to be doubly sure a fire is reported!

badly by playing around with these modes but they can be incredibly handy when used correctly. After some experimentation, I found that by holding both volume buttons down and plugging in the charging lead, I could enter 'upload mode', which allows a suitable ROM file to be copied from a computer or an SD-card and then installed onto the system.

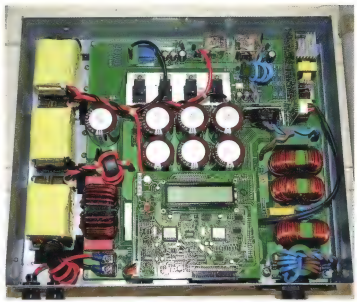
All I needed now was that package and I'd be away but as I said earlier, finding the custom ROMs created for these no-name tablets can be difficult. But then a stroke of luck; the manufacturer of the tablet had stored a copy of this file on the internal SD card and when update mode was entered, this file showed up as an available update. So, after agreeing to the warnings that installing it would wipe any previously-installed versions, I selected it and let Android do its work.

After about five minutes of watching the Android "man at work" and a slowly advancing progress bar, the tablet restarted and lo and behold, away it went.

A subsequent visit to some of the excellent forums on the web confirmed my suspicions that some manufacturers include a copy of their custom ROM with the device just in case disaster strikes. You can check this out by using the file manager app to peruse your internal storage media

for a likely-looking file. This could be named anything but as a general rule, these files usually need to be named "update.zip" to work. On the other hand, when searching and downloading from the web, they might be called something more descriptive, with a file name including the version of Android and the model number of the device.

The real trick might be finding how to enter the different modes and here Google can help. If you can't find any information about it, try pushing and holding different combinations of the volume, home and any other buttons while pushing the power button – you can usually trigger upload/download or recovery modes this way.



This is the view inside the CMS 2000 inverter with the cover removed. The switchmode power supply is the sub-board in the top right-hand corner.

Faulty solar panel inverter

Solar panel inverters typically cost $2000 or more but how many are discarded because of a minor fault? D. P. of Faulconbridge NSW recently saved himself $2000 by spending just 44 cents to replace one faulty component. Here's what happened . . .

We have a 3kW grid-connected solar system, consisting of two strings of nine solar panels, each string feeding a CMS 2000 (2kW) inverter. A few weeks ago, I noticed that one of the inverters was slow to start up in the morning. It was often at least 10am before it 'woke up' and on some days it didn't wake up at all. The other inverter would typically 'wake up' at around 7am.

A search of the Internet drew a blank, so this didn't appear to be a common problem with these inverters. The only possible clue was that the input voltage at which the inverter starts up is under software control. Apparently, this voltage is set to a default value by the firmware but can be adjusted via the inverter's serial port – if you have the right software AND you have the password for the inverter.

Anyway, all this was academic, because the CMS 2000 comes with a 5-year warranty. All I needed to do was to make a warranty claim and get the inverter repaired or replaced, right? Wrong!

On checking my paperwork, I found that the inverters were one month out of warranty! I called the company which had installed the system, explained the problem and asked them if they would stretch a point and honour the warranty anyway. "No" was the stern reply, "if we do it for you we will have to do it for everyone. In any case, those inverters are no longer made. We would have to replace both of your CMS 2000s with a single 3kW inverter. We can supply one for about $2000 including the wiring changes that would have to be made to your board".

My reaction to this was rather immoderate! Apart from the high cost and the company's inflexible attitude, it seemed outrageous to be throwing away one perfectly good inverter and another that possibly only needed a software tweak.

After some thought, I decided to take the inverter to the company's premises and see if I could convince them to at least have a look at it and determine whether it was fixable or not. As it turned out, my sudden appearance on their doorstep produced a welcome change in attitude. To my surprise (and to their credit), they told me that fixing it may just be a simple matter of re-flashing the EEPROM and they readily agreed to get one of their technicians to do it while I waited. What's more, when I expressed an interest in observing the process, they gave me permission to go into the workshop with him.

The technician was a nice guy and seemed ready to share his knowledge. First, he connected a specialised power supply (a fake solar panel) to the inverter. This provides a source of approximately 300V DC which, he explained, simulates a typical string of solar panels. No AC mains connection was made to the inverter, however. The technician explained that all the voltages needed for the various circuits in this inverter are derived from the DC input, so that was all that was need to install the firmware.

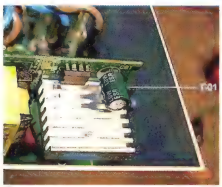
No sign of life

We immediately struck problems. The technician expected the inverter to start up under these conditions within a minute or so but there was no sign of life. I explained that this inverter was normally slow to start and told him that I thought it could be a software problem. He said that this was unlikely and opened up the case.

First, he checked all the Mosfets. These monsters were all OK fortunately, so he then did some voltage measurements. During these tests, he pointed out a small sub-board containing a switchmode power supply. This board takes the DC input from the solar panels via two of the Mosfets and generates the various voltages used in the inverter. It should start running as soon as there is 100V or more from the solar panels, well before the inverter proper starts up, but there was no output from it.

"Well, I'm afraid that's it," he said, "the inverter's kaput! We don't repair these things at a component level any more and as far as I know, there is no-one who does."

At that stage, I thanked the technician for his trouble and told him I thought I would have a go at fixing it myself. It seemed to me that this switchmode supply could not be all that different from the sort of thing found in computers or a thousand other devices these days – they accept a high-voltage DC input and produce



The switchmode power supply board with its new capacitor (C01) in place.

several low-voltage outputs. The main difference here was the source of high-voltage DC. Besides, I had a good one for comparison so what could possibly go wrong?

When I got back home, I spent some time thinking about the inverter's wake-up behaviour. Its slow wake-up was almost certainly due to a fault on the switchmode board and probably had nothing to do with the solar panel voltage or any software settings. Some other factor was causing it to wake up late. Could it be temperature? Was it starting up when the ambient temperature rose to a certain level?

A blast of hot air

I whipped the cover off and, with the aid of Mrs P's hair-drier, gave the power supply board a blast of hot air. Almost instantly the power supply sprang into life and the inverter began to go through its start-up sequence. I also noted that a low-level, high-pitched screeching noise which was coming from the switchmode board when it was in the fault condition immediately stopped when it came to life.

Placing a scope probe near the inverter transformer revealed a noisy, chaotic waveform when in the fault condition. However, this turned into a clean switching waveform once the supply began operating normally. So it looked like the supply was squegging when in the fault condition.

Using a paper cone with a small opening at the apex, I then tried directing a more localised stream of hot air onto individual components on the board. This approach quickly paid off because I soon identified an electrolytic capacitor, marked as C01 on the board, that seemed extremely heat sensitive. When checked with an ESR meter, it measured close to its marked capacitance of 220µF but its ESR was quite high at around 21Ω.

Replacing it restored the inverter to normal operation. Subsequent testing of the faulty capacitor then revealed that while its ESR was 21Ω when cold, this dropped to about 3Ω when it was heated moderately. Even at this level, it was maybe 10 times higher than it should have been and given that switchmode power supplies are notoriously sensitive to capacitors with excessive ESR, I was surprised that the supply operated at all with this capacitor in circuit.

Replacing a 44-cent capacitor is certainly a much better deal than forking out $2000 for a new inverter! It makes me wonder just how many "dead" inverters that actually had minor faults are now clogging up landfills, having cost people serious money to replace them.

Finally, a few words of caution to anyone contemplating working on one of these inverters:

(1) The output of a typical solar panel string is potentially lethal (several hundred volts DC), even when not in full sun. This voltage is present on several components in the inverter (even when the grid is not connected) and is potentially lethal;

(2) With the grid connected and the inverter operating, lethal AC and DC voltages are present on various components in the inverter and it's all too easy to come into contact with these parts if you aren't careful. In fact, I would not recommend operating the inverter with the cover off with the grid connected, if at all avoidable; and

(3) There are several large capacitors in the inverter which remain charged at lethal voltages for some time after the inverter has been shut down. The inverter should be left for at least 30 minutes after shut-down for these capacitors to discharge before doing any work on it and then only after you've checked these voltages with a DMM.

Motor start capacitor failure

B. R., of Beverley, WA recently encountered an unusual problem with an evaporative air-conditioner but there was a simple explanation. Here's his story . . .

We rent out the house next door to our property and, earlier in the year, our tenant called us one very hot afternoon to say that the evaporative air-conditioning wasn't working. I went over to check it out and on entering the house, I could hear the blower fan running on maximum. However, with the air-conditioning not working, the house was very hot inside, it being over 40°C outside.

I got my ladder and climbed onto the roof where I removed one of the wood fibre panels from the unit. This revealed that the water pump was working, as the water was pouring out over the pads.

A remote power switch is mounted inside the cooling head to aid servicing so I turned it off and had a look around. There were no obvious problems that I could see and when I turned the fan on, it started and went to full power with no problems. So everything appeared to be working but the unit wasn't cooling the house.

After poking around for awhile, it dawned on me that the fan was running in reverse and sucking hot air into the house through the gaps around the doors and windows. But why was it running in reverse? Well, the hot air rising from below and passing through the ducts was causing the fan to slowly rotate in reverse without any power applied. When power was applied, the motor started in that direction and that meant one thing – a faulty motor start capacitor.

Fortunately, I had a spare motor start capacitor in a junked unit. This was duly fitted and the motor now started in the correct direction. Full cooling to the house was then restored, much to the relief of our tenant. SC

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Ref: Silicon Chip Magazine September 2014

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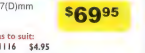

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Extremely bright 1450 lumens spot or flood beam work lights. Features waterproof IP68 rated alloy housing and stainless steel mounting hardware. 12/24V.

- Beam distance (spot/flood): 230m/125m
- Input current: 2.1A (12V), 1.1A (24V)
- Sold as a pair

Spotlights **SL-3934** $99
Floodlights **SL-3936** $99

NEW! $99 ea

2.4GHz Digital Wireless Reversing Camera

Quick and easy to install. Screen can be suction mounted to your windscreen and is directly powered from the cigarette lighter socket.

- Range up to 50m
- Infrared LEDs for reversing after dark

QM-3852

Spare camera **QM-3854** $84.95

$199

Dual Dash Cam with GPS

Includes HD 720p front facing camera and 480p rear camera. Features GPS to store position or route details and 95° wide-angle view lens. 12VDC.

- 2.7" LCD screen
- G-Sensor to detect sudden vehicle movement
- Automatic recording upon ignition start

QV-3844

$229

DEAL! FREE* 16GB MICROSD CARD VALUED AT $26.95 (XC-4989)

*Valid with purchase of QV-3844

In-Car FM Transmitter to suit iPhone 5®

A convenient way to playback music from your iPhone®5 Smartphone through the car's sound system. Includes Lightning charging connector.

- Built-in microphone
- USB output: 5V/800mA
- Size: 100(L) x 30(W) x 12(D)mm

AR-3127

$29.95

iPhone® not included

Smartphone Holder with FM Transmitter

Charge and play music through the FM radio in your car simultaneously. Connect your Smartphone or load your songs onto a microSD card (sold separately, 32GB XC-4992 $47.95). 12/24VDC.

- Dash mounted universal holder
- Supports MP3/WMA/WAV formats
- USB output: 5V/2.1A

AR-3128

iPhone® not included

DEAL Buy AR-3128 & XC-4992 for $72.90 Save $15

$39.95

Bluetooth Receiver with Microphone

Take phone calls and stream music from any Bluetooth® enabled device over your car/marine radio. 12VDC.

- Surface mount or flush mount (22mm cutout)
- One-knob volume and track control
- Bluetooth 4.0

AR-3129

$49.95

12V Power Accessories

Cigarette Lighter Socket to 8mm Eye Terminal

- 400mm long leads with 8mm eye terminals
- Rated to 15A max

PT-4451

$12.95

Cigarette Lighter Plug to Merit Socket Adaptor

- 300mm long lead with dustproof cover

PP-2098

$12.95

4 Way Power Splitter with USB

- 4 x 12VDC socket outputs (max 10A)
- 1 x 5VDC 1A USB port
- Mounting hardware included

PS-2019

$19.95

Auto Tuning Display Modules

Simple tuning tool to help in vehicle modification or monitor the behaviour of the engine control module. 10 LEDs show fuel mixture levels - rich, lean or normal. 12VDC.

- Size: 81(L) x 51(W) x 22(H)mm

Exhaust/Gas/Oxygen Sensor Module **AA-0374** $24.95

Battery Voltage/Airflow Meter/Oxygen Sensor Module **AA-0375** $24.95

NEW! $24.95 ea

Speedo Corrector Module

This smart module alters the speedometer signal up or down from 0% to 99% of the original signal. Extremely useful when you modify your gearbox, diff ratio or change to a large circumference tyre. 12VDC.

- Automatic input setup selection
- Size: 63(L) x 46(W) x 25(H)mm

AA-0376

NEW! $39.95

12V Thermoelectric Cooler & Warmer

Cools to 18-20°C below ambient temperature, and heats up to 65°C. Great for camping trips and work sites. Low noise, fully insulated and thermoelectric. Lightweight and portable.

- 12VDC powered
- 14L capacity
- CFC Free
- Size: 490(L) x 270(W) x 305(H)mm

GH-1373

$99

jaycar REWARDS

REGISTER ONLINE TODAY!

SIGN UP NOW & BE REWARDED

Earn a point for every dollar spent at any Jaycar Company store* & be rewarded with a $25 Rewards Cash Card once you reach 500 points!

*Conditions apply. See website for T&Cs

Register online today by visiting www.jaycar.com.au/rewards

8A Heavy Duty Battery Charger

Suitable for both 6 and 12 volt car, boat, motorcycle and lawnmower batteries up to 6 amps. Switchable between trickle or heavy duty charge rates.

- 4-stage LED charge indicators
- Overload and reverse polarity protection
- Complies with Australian Electrical Safety Regulations

MB-3522

$59.95

High Power Pure Sine Wave Inverters

Suitable for a variety of mobile and permanent power installations. Provides standard protection (overload, high temperature, over/under input voltage and output short circuit) as well as host of additional features to improved performance and reliability under adverse conditions. Range from 180 to 2000W.

- USB port
- 12VDC input, 230VAC output

100W	MI-5706 WAS $649	NOW $549	SAVE $100
500W	MI-5708 WAS $899	NOW $799	SAVE $100
2000W	MI-5710 WAS $1149	NOW $999	SAVE $150

See online for Modified Sine Wave Inverters

FROM $549
SAVE UP TO $150

MI-5710

140A Dual Battery Isolator Kit

Allows two batteries to be charged from your engine alternator at the same time. The isolator automatically engages and disengages depending on the charge condition of the start battery. Supplied as full kit with wiring hardware. See website for full contents.

- Voltage rating: 12VDC (max 15VDC)
- Cut in/off voltage: 13.7/12.8 VDC

MB-3686

$139

Also available:

Standalone Unit Without Wiring Hardware
MB-3685 $79.95

Semi-flexible Solar Panels

These 12V flexible solar panels offer performance at anaffordable price. No heavy rigid frame makes them light and portable. Both units have a fully sealed terminal box with approx 1.2m of power cable with PVC outer sheath.

20W
- Short circuit current: 1.24A
- Weight: 0.78kg

ZM-9112 $99.95

100W
- Short circuit current: 5.69A
- Weight: 2.8kg

ZM-9116 $399

FROM $99.95

Note: Limited stock. Not available online.

1000VA On-Line Pure Sine Wave UPS

A true On-Line UPS featuring 2 power sources (battery and mains) to ensure instantaneous transfer time in the event of a power failure. This UPS has a 2U rack height, and can be mounted in standard 19" rack set up or used in a tower configuration.

- 1000VA/700W rated / 6 x IEC power outputs
- 32 mins backup time at high load
- Size: 440(W) x 350(D) x 56(H)mm

MP-5212

$499

DEAL! Buy MP-5212 & HB-0454 for $519 Save $49
2U Fixed Rack Shelf valued at $69

High Power 4 Stage Wall Mount Battery Chargers

Tough mains powered high power battery chargers designed to quickly recharge 12V lead-acid batteries. Smart 4-stage charging to ensure battery life is maintained by monitoring and charging the batteries safely, resulting in a charger that is safe to leave connected indefinitely. Over-charging and ouput short-circuit protected.

- Bulk/Absorption: 14.2VDC / 14.6VDC / 14.8VDC
- Float charging: 13.2VDC / 13.5VDC / 13.8VDC
- Efficiency: Up to 88%

15A	MB-3710 WAS $219	NOW $189 SAVE $30
40A	MB-3715 WAS $399	NOW $359 SAVE $40

FROM $189
SAVE UP TO $40

150Ah Sleek AGM Deep Cycle Battery

Designed to perform in harsh tropical conditions! With a superior high rate discharge performance and higher cycle service life, this battery is perfect for a wide array of applications including remote solar systems, 4WD, caravan, RV, motorhome, and marine. 12VDC. See our website for full specs.

- Small footprint to suit installations in tight areas
- Weight: 52kg
- Size: 123(W) x 556(D) x 296(H)mm

SB-1822

NOTE: Not stocked in all stores but can be ordered. Call your nearest store for details

$699

Digital DC Power Meters

This digital power meter displays both the continuous and peak voltage, current, and power. Cumulative amp hours and watt hours consumed are also stored allowing you to monitor the system over time. Suitable for DC operation from 5 to 60V. An ideal addition to low voltage DC circuits on boats, caravans, or solar systems.

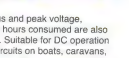
- Size: 41(L) x 45(W) x 23(D)mm

Digital DC Power Meter with Internal Shunt
- Current Range: 0-20A

MS-6170 (Shown)

MS-6170

$69.95



Digital DC Power Meter to suit 50mV External Shunt
- Current Range: 0-200A depending on shunt

MS-6172 $74.95

USB Data Adaptor
Enhance data collection of the digital DC power meter by connecting to your PC with this USB data adaptor.

- Size: 45(L) x 35(W) x 18(H)mm

MS-6174

$79.95

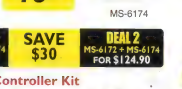
Data Adapter

MS-6174

DEAL 1 MS-6170 + MS-6174 FOR $119.90
SAVE $30
DEAL 2 MS-6172 + MS-6174 FOR $124.90

Wireless 3 Outlet Mains Controller Kit

Plug in any mains appliance rated up to 10A and use the remote to turn each one on or off individually, or control all of them together. One of the outlets also has a LED night light that is operated with the remote.



- 10A 2400W rated

MS-6142

$44.95

Spare Mains Outlet/Light MS-6143 $17.95
Spare Mains Outlet/Light with Remote MS-6145 $24.95

Regulated Variable Laboratory Power Supplies

This precision, automatic transfer type power supply provides stable voltage and current with regulated output voltage. Features coarse and fine voltage controls. Ideal for scientific research, education, electronics and electrical equipment repair.

- Output voltage: 0 - 32VDC (Each)
- Output current: 0 - 3 Amps (Each)

Single Output MP-3086 $199
Dual Output MP-3087 $349 (shown)

FROM $199

Wi-Fi Multi Card & USB Reader

Share and transfer files from memory cards/USB storage devices wirelessly between computers, Tablets and Smartphones using a secure Wi-Fi hotspot.

- Up to 20m Wi-Fi range, maximum 8 simultaneous users
- Rechargeable, USB charge cable included
- 105(L) x 65(H) x 11(D)mm

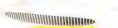
YN-8426

NEW!

$59.95

Wireless AC750 Dual Band Router

Powerful 802.11ac router with Wi-Fi speeds of up to 750Mbps. Stream HD movies over Wi-Fi, transfer large files quicker using the 5GHz band or the option of 2.4GHz for general internet browsing. Features 4 x 10/100 ethernet ports, WPA/WPA2, firewall protection and QoS for critical operations.



- Functions as a router, access point, range extender, Wi-Fi bridge or WISP

YN-8329

NEW!

$99.95

High Power Wireless Outdoor Router/Range Extender

With a wireless power of 600mW this unit has excellent point-to-point range with the built-in 9dBi directional antenna. Ideal for long range or building-to-building wireless network.

- 802.11b/g/n standards
- LAN port 10/100 (featuring PoE)
- Wireless data rate up to 150Mbps

YN-8330

$89.95

8 Port N-Way Ethernet Switches

Enhance network performance and efficiency. Mains powered or via USB port. Supports auto-negotiation and cable length detection. Power supply and USB power adaptor included.

- 8 x RJ-45 ports
- Size: 137(L) x 76(W) x 25(H)mm

10/100Mbps Switch YN-8077 $24.95
10/100/1000Mbps Gigabit Switch YN-8078 $59.95

FROM **$24.95**

3G/4G Antennas

Using 3G/4G wireless Internet in certain areas may require the help of an antenna to boost the signal for a reliable flow of data. Both antennas features a very strong magnetic base so you can fix it to the roof of your car or any other steel surface.

- Supports 850, 1900, and 2100MHz
- Terminated with FME connector

5dBi, 300mm long with 2m Cable AR-3310 $49.95
7dBi, 960mm long with 3m Cable AR-3312 $69.95

FROM **$49.95**

RS-485/422 to USB Converter

Wire up an RS-485/422 device to the 4 socket terminal block to give your hardware USB connectivity. Surge protected. Suitable for industrial, military, marine, science and custom built applications.

- 610mm USB A Male to Male cable included
- Size: 55(L) x 42(W) x 24(H)mm

XC-4132

$79.95

19" Rack Mount Solutions

6U Cabinets

Ideal for studios, PA, sound reinforcement, IT, or phone systems installations. Features 1.8mm solid steel powder coated cabinets with clear tempered glass doors.

- Size: 530(W) x 360(H) x 450(D)mm
- Key lockable

Flat Packed HB-5170
Was $159 Now $129 Save $30
Assembled HB-5171
Was $189 Now $149 Save $40

FROM **$129**
SAVE UP TO $40

1U Sliding Rack Shelf

Ideal for mounting computer keyboards or other equipment that needs to be accessed easily. Ball bearing runners for smooth operation.

- Max 20kg load
- Size: 483(W) x 52(H) x 350(D)mm

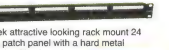
HB-5450

$99

Also available:
1U Fixed Rack Shelf HB-5452 $49

See online for our wide range of highest quality swing frame cabinets, blank panels, cable management accessories & punch-down tools!

1U 24-Port Patch Panels



Sleek attractive looking rack mount 24 port patch panel with a hard metal exterior. Numbered ports and a labelling area for each port.

- Includes instruction stickers on the back

Suits Cat5e YN-8046 $49.95
Suits Cat6 YN-8048 $69.95

$49.95

2W UHF Transceiver with CTCSS

A standalone 80-channel transceiver with auto power-saving 500mW mode. Features CTCSS function, dual watch, Vox, auto squelch function and low battery display. Includes a Li-ion rechargeable battery and AC adaptor.

- Range up to 10km line-of-sight
- Backlit LCD

DC-1049

$69.95

FREE* CAR CHARGER
VALUED AT $17.95 (DC-1035)

*Valid with purchase of DC-1049

3W UHF Floating Transceiver with CTCSS

A robust floating 80-channel transceiver featuring CTCSS function, Hi/Lo power output, auto squelch function and low battery display. Includes a Li-ion rechargeable battery, AC adaptor and charging cradle.

- Fully submersible, IP67 rated
- Range up to 10km line-of-sight
- Backlit LCD

DC-1074

$119

3W VHF Floating Transceiver

Essential for boating. Covers all international VHF marine channels so you can call for help when needed or communicate with other boats. Includes a Li-ion rechargeable battery pack, AC adaptor, charging cradle and belt clip.

- Fully submersible, IP67 rated
- Switchable output power
- One touch emergency CH16
- Backlit LCD

DC-1093

$99

High Quality Cables for Your Next Project

15A DC Power Cable

- AWG: 16, single core
- Ideal for automotive and marine applications
- Sold in handy pack 10m reel

Red WH-3054 $12.95
Black WH-3055 $12.95
Green WH-3056 $12.95

$12.95 /roll

RG59 / 16G Power Cable

- AWG: 24
- Ideal for CCTV and surveillance applications
- Black

WB-2017

$1.40 /m

50Ohm RG58U Cable

- AWG: 23, single core
- Suits up to 500MHz
- Ideal for CB, marine and two-way radio

WB-2010

$1.45 /m

Both the WB-2017 & WB-2010 are also sold in 100m rolls in-store or online

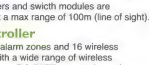
Low Cost Home Automation

Don't spend tens of thousands of dollars to create a smart home. With our new low cost range of Wireless Home Automation, you can create a fully automated system and only spend a few hundred dollars.

Simple and easy to use, all sensors, controllers and swicth modules are operating wirelessly on 433MHz frequency at a max range of 100m (line of sight).

Home Automation Main Controller

A powerful controller with built-in 16 wireless alarm zones and 16 wireless home automation control. Easily interfaces with a wide range of wireless security devices such as a PIR motion detectors (LA-5157), magnetic reed switches (LA-5158), light sensors (LA-5598) and remote key fobs (LA-5155) to protect your home and property.



- Timer schedule programming
- Group programming
- Matrix (Scenes) programming
- 100 Alarm event memory
- 12VDC
- 240VAC power adaptor included

LA-5592

NEW!

$119

Accessories to suit:

Key FOB Remote	**LA-5155 $19.95**
PIR to suit	**LA-5157 $49.95**
Wireless reed switch to suit	**LA-5158 $39.95**

Wireless Bell Box

Works as an audible and visual deterrent, the siren produces a wailing 94dB of output and a powerful strobe when alarm is activated. Supplied with 240VAC mains power adaptor.

- Voltage input: 12VDC
- Wireless Range: 100m line of sight
- Wireless Frequency: 433MHz
- Size: 340(L) x 200(W) x 75(D)mm

LA-5579

NEW!

$109

240VAC Mains Switch Controller Module

Designed to be hard wired to your GPO, wall switches or other mains device, it enable you to remotely activate any mains appliances.

- Voltage input: 240VAC
- Wireless Range: 100m line of sight
- Wireless Frequency: 433MHz

LA-5594

NEW!

$39.95

Also available:

12VDC Switch Controller Module	**LA-5595 $59.95**
240VAC Mains Light Dimmer Module	**LA-5596 $39.95**

*Note: A licensed electrician is highly recommended to hard wire this device into 240V mains wiring.

Wireless Light Sensor Module

Interfaces with the home Automation System to turn an output device on or off.

- Adjustable light setting
- Voltage Input: 12VDC
- Wireless Range: 100m line of sight
- Wireless Frequency: 433MHz

LA-5598

NEW!

$39.95

Wireless Infrared Controller

Mount on the roof to directly control your household appliances. Will learn your appliances infrared remote command and repeat them when matched with a home automation input device.

- Up to 150m² size of operation
- Voltage input: 12VDC
- Wireless Range: 100m line of sight
- Wireless Frequency: 433MHz

LA-5597

NEW!

$79.95

Day/Night Wi-Fi IP Cameras

Features Wi-Fi and wired connectivity, easy setup and configuration options, and motion alarm detection. Remote viewing and control via web browser or Smartphone App.

FROM **$99**

- M-JPEG video compression
- Up to VGA 640x480 @30fps

Pan/Tilt Model	**QC-3834 $99**
Outdoor Model	**QC-3836 $119 (shown)**

Peephole Viewer with Image Capture

Displays video from the other side of your door on a clear 3" LCD screen. MicroSD card required for image capture (sold separately XC-4992) triggered by adding either the knock or PIR sensors (sold separately).

- Requires 2 x AA batteries
- Peephole tube diameter: 12mm
- Peephole tube length: 33 to 45mm
- Viewer size: 158(H) x 87(W) x 32(D)mm

QC-3735

$225

BUY BOTH QC-3735 & QC-3737 FOR $249 SAVE $20.95

Also available:

PIR Motion Sensor	**QC-3736 $84.95**
Vibration Knocking Sensor	**QC-3737 $44.95**

8 Channel Network DVR

Value for money DVR with 500GB HDD. Records up to full 960H or D1 resolution at 25 frames per second on each channel. Recording can be triggered manually, by timer, alarm input, or motion. Just add cameras to record and view.

- H.264 video compression
- Remote viewing via Smartphone App

QV-3037

$499

Camera to suit QC-8634 $149

Biometric Finger Scan Safe

Provides secure storage using a finger print scan for fast and simple access in as little as 2 seconds! Features a built-in flash memory and ideal for storing money, passports etc. Mounting hardware included.

- 1m alloy security cable
- Requires 4 x AA Alkaline batteries
- Size: 273(L) x 190(W) x 51(H)mm

HB-5457 WAS $99

$79

SAVE $20

Wireless FM Intercom

Perfect for communicating around your home or office. Built-in monitor function. Mains powered and transmits through house electrical wiring.

- 2 channels
- Sold as a pair

AI-5500

$74.95

GPS/GSM Tracking Device

Locate and track the whereabouts of your vehicle in real time via the Internet on a computer or Smartphone. It works by sending the vehicle's GPS coordinates via the GSM network (Sim card not included) to the free online tracking service, which shows the location on Google Maps.

- Built-in GSM & GPS antenna
- Features remote engine immobilisation, SOS/panic alerts, over speed or area detection alerts
- Very low 1 to 2mA standby current
- Size: 68(L) x 48(W) x 20(D)mm

LA-9011

$149

4 Channel Remote Control Relay Kit

Control up to 4 different devices with a single controller and key fob remote. Each of the 4 channels can be independently configured to momentary or latching mode via DIP switch. Ideal for access control applications.

- Range up to 30m (300m+ max line of sight)
- 2 key fobs included

LR-8824

Spare Wired Transmitter	**LR-8819 $39.95**
Spare Remote	**LR-8829 $24.95**

$99

3G SDI & HDMI Converters

Allows HDMI equipped TVs and PC monitors to playback uncompressed 2.970Gbps digital footage from cameras supporting this format. Provides an alternative way to transmit HDMI over long distances.

- Size: 80(L) x 43(W) x 23(H)mm

3G SDI to HDMI Converter **AC-1727 $99.95**
HDMI to 3G SDI Converter **AC-1729 $99.95**

NEW! **$99.95 ea**

HDMI Audio Extractor

Extracts the audio from HDMI and outputs to a 3.5mm socket or S/PDIF, allowing you to connect audio to a better sounding system. Comes with a 3.5mm to RCA audio cable.

- Supports video up to 4K x 2K, audio up to 5.1CH digital
- HDMI 1.4 compliant, HDCP support
- Size: 61(L) x 54(H) x 20(H)mm

AC-1741

NEW! **$79.95**

Composite AV Cat5 Balun with IR Receiver

Transmit crystal-clear audio and video signals over long distances via economical Cat 5 cable. You can also use it for extending the range of your remote control. The signals can be transmitted up to 300 metres on UTP.

$89

- Size: 64(W) x 73(D) x 29(H)mm

QC-3681
Spare IR Receiver AR-1819 $19.95

Multi-coloured LED Party/Stage Lighting Kit

This stage lighting kit features 4 extremely thin LED PAR lights with a stand extendable up to 1.8m, 3 modes of operation (DMX, Master/Slave and sound activation), RGB colour mixing and advanced LED technology. Each unit features 145 bright red, green and blue LEDs PAR CAN. Includes a light and stand carry bag plus a foot controller.

- DMX Channel: 13
- Mains powered
- Light carry bag: 700(L) x 390(W) x 200(H)mm

SL-3467 WAS $399

$349 SAVE $50

LCD Monitor Wall Brackets

Get your TV into the best viewing position. Both models compatible with VESA mounting.

Single Arm
- Max weight: 5kg
- Swivel: 120° left & right
- Tilt angle: 20° up and down

CW-2814 $39.95

Double Arm
- Max weight: 22kg
- Swivel: 160° left & right
- Tilt angle: 5° up, 20° down

CW-2813 $69.95

CW-2813

FROM **$39.95**

4 Input HDMI Switcher with Audio Return

Switch between four HDMI sources to one HDMI equipped display. Features ARC to allow audio signals to be returned from the TV display to sound system.

- Inputs: 4 x HDMI
- Outputs:HDMI, TOSLINK, 3.5mm stereo
- Supported resolution: Up to 4k x 2k / 3D TV support / 1080p / 1080i / 720p / 720i
- Digital Audio Support
- Dolby TrueHD
- DTS-HD Master Audio 7.1CH
- Size: 191(L) x 83(W) x 25(H)mm

AC-1709

Also available:
4 x 2 HDMI Switcher/Splitter with UHD 4k Support AC-1714 $119

NEW! **$119**

VGA & R/L Audio to HDMI Scaler Converter

Accepts both VGA and left/right audio inputs for use with the latest digital HD TV.

- HDMI resolution fixed to 1280x720p
- Size: 88(L) x 68(W) x 25(H)mm

AC-1617

$99

AC3/DTS Digital to Analogue Audio Converter

Convert digital audio sources that use Dolby Digital AC3 Pro logic, DTS, PCM or other formats into 2.0 channel analogue audio output. A convenient turnkey solution for audio connectivity differences.

- Inputs: 1 x TOSLINK/SPDIF, 1 x Coaxial
- Outputs: 2 x RCA (L/R), 1 x 3.5mm AUX
- Size: 72(L) x 55(W) x 20(H)mm

AC-1658

$99

19" Rack Mount DMX Controller

Control multiple DMX devices, such as lights, dimmers, fog machines or laser shows with preprogrammed scenes such as fade, pan, strobe, colour etc. Rack-mountable and mains powered.

- Control up to 12 devices
- 16 channels per device
- 9V plugpack included
- Size: 482(W) x 133(H) x 70(D)mm

SL-3429

$149

Also available:
5 Channel DMX Controller SL-3423 $89.95
5 Channel 94 LED Par Light SL-3424 $99

DEAL
Buy SL-3429 or SL-3423 & Get 20% OFF SL-3424

Ultra Slim LED/LCD Wall Mounts

Ultra thin wall brackets to mount your LED/LCD TVs for optimal viewing experience. Heavy duty steel construction. Mounting hardware and instructions included.

- Load capacity up to 25kg
- VESA standard compliant

Tilting Models:
- 15° of tilt
- 19mm mounting profile

For 23" - 55" TV CW-2836 $39.95
For 40" - 65" TV CW-2838 $49.95

Pan/Tilt/Swivel Model:
- 15° tilt/180° swivel
- 32mm mounting profile
- 642mm max extension

For 32" - 55" TV CW-2852 $119

CW-2836 CW-2852

FROM **$39.95**

TCP/IP Cat5e HDMI Extender with IR Repeater

Utilises the TCP/IP protocol to extend a HDMI source up to 100m away over a common Cat5e/6 cable. Ideal for setting up multiple displays over long distances.

- Up to 1080p resolution
- IR repeater function
- Power supplies included

AC-1680

$189

Also available:
Extra Receiver to Suit AC-1701 $79
Wall Plate TCP/IP Cat5e HDMI Extender AC-1659 $129

HDMI Converter Leads

DVI-D Plug to HDMI Plug

- 1.5m long

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Digital effects processor for guitars & musical instruments

By NICHOLAS VINEN

This deceptively simple unit provides 10 different musical instrument effects, including echo, reverb, tremolo, fuzz, compression, flanging and phasing. Each effect is adjustable and can be defeated with a foot pedal switch. It's designed for use with electric guitars but will work with other instruments and vocals too.

WANT TO SPICE up your guitar performances? Build this Digital Effects Processor into a guitar amplifier and you will get many different effects to play with, without needing to lug around and wire up many different effects pedals. It can apply the majority of common effects to a line-level signal and you can adjust them to suit your needs.

We can't promise that this will replace all your effects units but it certainly gives a lot of different options which suit a variety of instruments, performers and musical styles. The idea is to build it into a guitar amplifier by connecting it between the preamplifier and amplifier sections. It can be powered directly from an amplifier supply rail, assuming a suitable DC voltage is available, or the supply rail can be derived, creating one very convenient package!

But it is not just intended for use with guitars. It is suitable for use with a large variety of other musical instruments, whether they are keyboards or instruments with pickups. And they can be used to enhance vocals as well.

Basically, if you want to add some pizazz to your performance, this Digital Effects Processor is a great way to do it.

Digital effects

The available effects are shown in Table 1. For each effect, there are two parameters which can be set using potentiometers VR3 and VR4. Those parameters are also listed in the table and described in the list of effects below.

Note that when one of the enabled

effects causes a reduction in signal level (eg, echo or reverb), the level for all effects is reduced, as well as the level when no effect is selected, in order to prevent noticeable changes in signal when switching between them.

The available effects are as follows:

- **Echo:** delays and attenuates the incoming signal, then mixes it back in for the output. VR3 adjusts the delay between (nearly) 0ms and 1200ms with an exponential curve, to make it less sensitive at the shorter end, which is more useful. VR4 adjusts the amount of attenuation; at higher settings, the echo is louder. Note that as the echo becomes louder, the original signal must become quieter to prevent overload.
- **Reverb:** the same as echo, except that many extra short echoes are added to simulate reflections from multiple hard surfaces in close proximity.
- **Tremolo:** the output volume is modulated by a sinusoidal waveform. VR3 adjusts the amount of modulation (ie, 'depth') while VR4 changes the frequency.
- **Vibrato:** the output frequency is modulated by a sinusoidal waveform. VR3 adjusts the amount of modulation (ie, 'depth') while VR4 changes the frequency. Note that this is performed by slightly speeding up and slowing down the audio signal although the change in delay that this causes should be imperceptible.
- **Overdrive:** this provides adjustable clipping for the signal. VR3 adjusts the gain applied to the signal and once the amplitude is high enough, it clips. VR4 adjusts how progressively the clipping occurs; at minimum setting it is hard, resulting in a square wave while at higher settings for VR4, the clipping is more progressive and the waveform becomes rounded.
- **Fuzz:** the same as overdrive except that the gain is applied asymmetrically, in order to inject extra distortion into the signal.
- **Compression:** the gain is slowly increased until the output reaches 90% of maximum. If the output exceeds this 90% level, the gain is decreased. VR3 sets the rate of increase while VR4 sets the rate of decrease. The scale for VR4 is different for VR3 as the rate of decrease is normally much higher.
- **Noise gate:** similar to but not quite the opposite of compression. When the input signal is below the threshold, there is no output. When the input goes above the threshold, it is sent to the output. VR3 adjusts the threshold while VR4 adjusts the hysteresis, to prevent the output from fluctuating on and off with a signal near the threshold.
- **Flanger:** this mixes the input signal with a version of the signal that has slight vibrato applied, causing a distinctive 'comb filter' Doppler effect.
- **Phaser:** similar to flanger but mixes the signal with a version that has a modulated phase shift, causing a 'rippling' effect which makes the sound seem artificial.

Features & Specifications

- 10 effects to choose from: Echo, Reverb, Tremolo, Vibrato, Overdrive, Fuzz, Compression, Noise Gate, Flanger and Phaser
- Each effect has two adjustable parameters
- Maximum echo/reverb delay: 1.2 seconds
- Four-position switch selects between three effects and no effect with seamless transitions
- Optional defeat switch (eg, foot pedal)
- Low noise and distortion: THD+N typically <0.02%, signal-to-noise ratio >76dB
- Two power supply options: 3.5-6V DC or 7.5-12V DC; current drain 60-80mA
- Optimal input signal range: 0.5-2V RMS
- Line output signal: typically 1V RMS
- Input impedance: 4-6kΩ
- Optional headphone output
- Optional microphone preamplifier

Modes

The effects are selected using a 4-position rotary switch (a slide switch could also be used). The second position selects no effect and the other three positions can each select one of the 10 effects listed above. We've made the second position the 'off' position to make it easy to switch between two commonly used effects and none.

A pushbutton is used to change which effect is selected by each switch position and is also used when adjusting the two knobs, so that different settings can be used for each effect and they don't have to be reset each time a different effect is used.

The same effect can be used with different settings for each switch position. If you don't need three effects, the switch can be limited to fewer positions. There is also a simple fall-back mode available; if the pushbutton is permanently shorted out (say, on the PCB) then the three effects selected by the rotary switch are always echo, reverb and tremolo and VR3 & VR4 can be adjusted at any time.

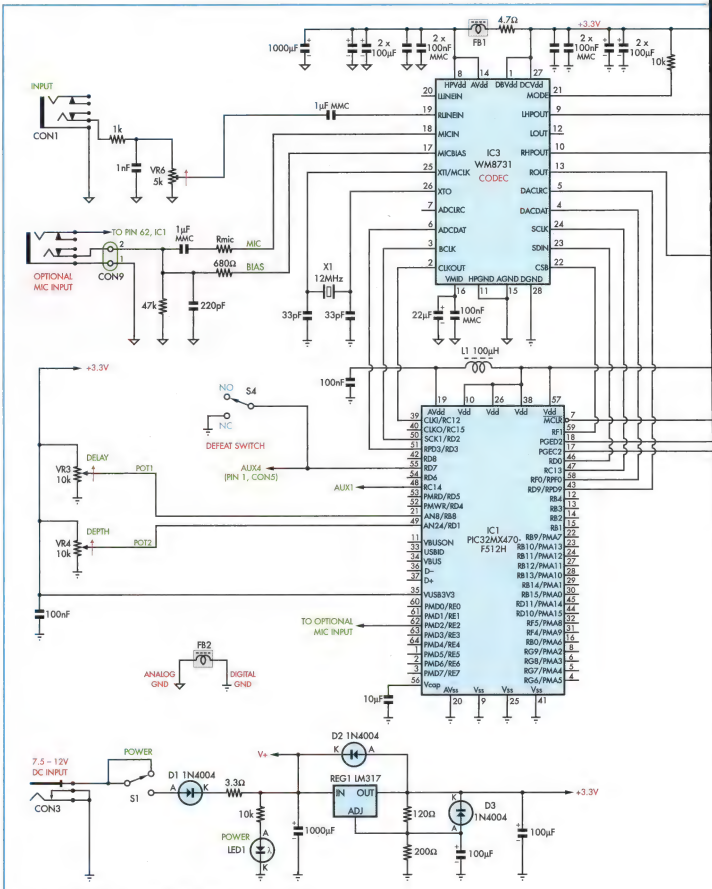
A defeat switch (eg, a foot switch) can be added and this has the same effect as switching the rotary switch to the 'off' position as long as it is held down. Or you can wire it the other way around, so that effects are only applied when the switch is held down.

Options

This Digital Effects Processor uses

Table 1: Effects Controls

#	Effect	VR3	VR4
1	Echo	Echo Delay	Echo Fall-Off
2	Reverb	Reverb Delay	Reverb Fall-Off
3	Tremolo	Amplitude	Rate
4	Vibrato	Amplitude	Rate
5	Overdrive	Gain	Softness
6	Fuzz	Gain	Softness
7	Compression	Attack	Decay
8	Noise Gate	Threshold	Hysteresis
9	Flanger	Amplitude	Rate
10	Phaser	Amplitude	Rate



DIGITAL EFFECTS PROCESSOR

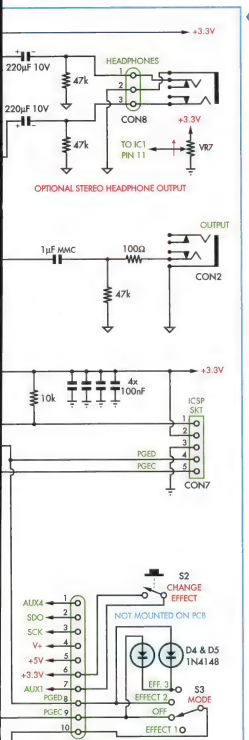


Fig.1: the basic Digital Effects Processor circuit. The incoming audio analog signal at CON1 is digitised by CODEC IC2 and then fed to IC1 where it is processed and then sent back across the same digital audio bus to IC2. A DAC in IC3 then converts it back into an analog signal which is fed to the output (CON2).

the same hardware as the Stereo Echo & Reverb Unit (February 2014) and the Dual Channel Audio Delay (November 2013). However, we have removed a number of components which aren't needed. For example, most musical instruments are not stereo so components are only fitted for one channel (and indeed, the software only supports one channel).

As with those earlier designs, it is possible to add extra components to provide a microphone input or stereo headphone output. The processed mono signal is sent simultaneously to both headphone output channels.

The headphone output could be useful for monitoring purposes. It's up to you whether you want to install the few extra components required which are shown in the circuit diagram at upper-right and on the overlay diagram, labelled in green.

The microphone input is less useful as its signal-to-noise ratio is only average. For a musical performance, you would be better off using an external microphone preamplifier such as our High-Performance Microphone Preamplifier from the September 2010 issue, which can run from the same DC voltage source as the Digital Effects Processor unit.

Software

In adding these new effects to the software, we have made some other changes at the same time. By making it process only a mono signal, this doubles the maximum echo to 1.2 seconds without needing an external RAM chip. This is more than long enough for instrumental work and so we haven't even bothered to provide the option of extra RAM in the software.

We've also gone to some effort to make changes between effects and changes in effect settings 'seamless' so that clicks and pops are not generated during a performance, even if settings such as echo delay are adjusted live.

Circuit description

The circuit diagram of the Digital Effects Processor is shown in Fig.1. As stated earlier, this is a simplified version of the circuit for the Stereo Echo & Reverberation Unit from the February 2014 issue, with unnecessary components removed. That's why there are so many unconnected pins on IC1; those originally used for interfacing with the unused SRAM chip and USB socket are not connected to anything.

A line level signal, from a guitar preamp, mic preamp etc is fed into CON1 (connector tip). RF signals that may have been picked up are rejected by a low-pass filter comprising a 1kΩ series resistor and 1nF capacitor to ground, while 5kΩ trimpot VR6 is used to reduce the level to no more than 1V RMS, the limit of what the CODEC can handle.

The signal is then AC-coupled to the right channel input of the CODEC (IC3) via a 1µF DC-blocking capacitor. A half-supply (~1.65V) DC bias for this input is provided by the IC itself

Alternatively, a microphone signal can be applied to a 3.5mm jack socket connected to pin header CON9 and this is coupled to IC3's microphone input pin (pin 18) via a 1µF capacitor and optional series resistor (Rmic) which reduces the amount of gain if fitted; otherwise it is linked out. IC3 can supply a bias current for electret microphones and this is fed via a 680Ω series resistor. The associated 220pF capacitor provides some RF filtering for the microphone signal.

The microphone input is selected when the RE2 input of IC1 (pin 62) is pulled low. This is wired to the microphone socket so that the sleeve of the mono jack plug shorts it to ground when it is inserted. When this line is open-circuit, the line input is the active input. If the microphone input is not needed, the components in the pink box at left do not need to be installed.

CODEC operation

Whichever signal is selected, it is digitised by IC3 with a sampling rate of around 40kHz and the resulting PCM digital audio signal is transmitted to PIC32 microcontroller IC1 via an I^2S bus. This appears at pins 3, 5 & 6 of IC3 which are the serial bit clock, sample clock and serial data line respectively. These connect to the audio CODEC compatible SPI peripheral in IC1.

IC1 reads the digital audio data from the CODEC, processes it to add the se-

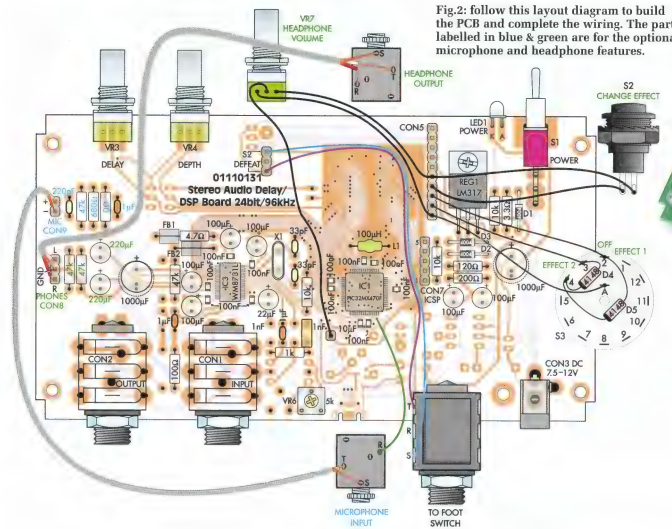


Fig.2: follow this layout diagram to build the PCB and complete the wiring. The parts labelled in blue & green are for the optional microphone and headphone features.

lected effect (depending on the mode) and also stores it within its 128KB RAM, for the echo and reverb effects. Processed audio data is sent back over the same I²S bus, this time to pin 4 of IC3 but timed using the same clock lines. The CODEC then converts this digital stream back to analog audio data which it transmits from its line out (pin 13) and headphone out (pins 9 & 10).

These signals are all AC-coupled to the respective output connectors, to remove the 1.65V DC bias, via a 1µF capacitor for the line output and 220µF capacitors for the headphone outputs. The reason the headphone output needs much larger capacitors is that the headphones will have a much lower impedance than the line input of other equipment; 8-600Ω for headphones compared to several kilohms for a line input.

The line output also includes a 100Ω series resistor, both to prevent cable capacitance from causing instability in the output drivers of IC3 and to protect IC3 against a shorted output.

IC3 also contains a digital volume control which adjusts the headphone amplifier output. If VR7 is fitted to the board, IC1 detects this and sends commands to IC3 so set the headphone volume depending on the voltage at VR7's wiper. If VR7 is not fitted, the headphone outputs are disabled and in that case, the other components in the pink box may be omitted.

Controls & power supply

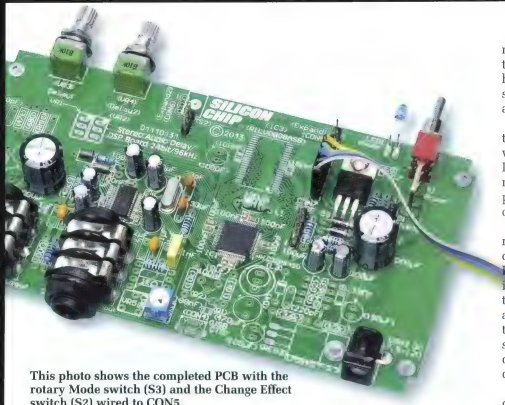
Pots VR3 and VR4 are used to change the effect parameters. These form voltage dividers across the 3.3V supply rail and the wiper voltage is read by IC1 using its internal analog-to-digital converter (ADC).

The power supply is quite simple. D1 provides reverse polarity protection while REG1 drops the incoming 7.5-12V rail to a regulated 3.3V, as required by IC1 & IC3. LED1 indicates when power is applied. IC1 and IC3 have 100nF bypass capacitors for each pair of supply pins, plus a 10µF capacitor for IC1's internal core regulator (on pin 56, Vcap).

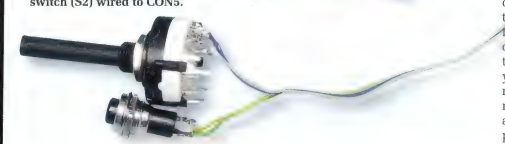
CODEC IC3 also has 100µF bypass capacitors for each supply pin to ensure a low supply impedance and thus good performance. Its analog and digital grounds are separated by ferrite bead FB2 to minimise digital noise coupled into the analog ground, where it could otherwise reach signal paths. A 4.7Ω series resistor also provides audio-frequency low-pass filtering for the analog supply, in conjunction with the 1200µF of capacitance on the analog supply rail (ie, 1000µF plus 2 x 100µF).

5V operation

As with the Echo & Reverb unit, you can change some components to operate the unit from a 5V supply such as is available from a USB port. This



This photo shows the completed PCB with the rotary Mode switch (S3) and the Change Effect switch (S2) wired to CON5.



arrangement is shown in Fig.3. Basically, REG1 and its associated components are deleted and an LM3940 low-dropout 3.3V linear regulator is substituted. This is necessary because the LM317 used for higher voltage supplies drops too much voltage and can't operate from 5V. Also D1 is replaced with a 1N5819 Schottky diode which has a much lower forward voltage.

Construction

Fig.2 shows the parts layout on the PCB (code 01110131). If building the 5V-powered version, refer also to Fig.4 for the necessary changes to fit the different regulator and Schottky diode (D1).

Start by fitting SMDs IC1 and IC3 (IC2 is left out). In each case, place the IC alongside its pads, right-side up and identify pin 1 (there should be a depression in one corner but magnification may be required to spot it). A pin 1 dot is also shown on the overlay diagram and PCB.

Apply a very small amount of solder to one of the corner pads. If you are right-handed, it's easiest to start with the top pad on the right side or if left-handed, with the top pad on the left side. Avoid getting any solder on the adjacent pad.

Now, pick up the part with a fine-tipped pair of angled tweezers and while heating this pad, gently slide the IC into place. Check the part's alignment under a magnifying lamp. All the pins must be centred fairly accurately over their respective pads.

If they aren't, don't panic, it's just a matter of re-melting the solder on that one joint and carefully nudging the IC in the required direction, then re-inspecting it. It may take a few attempts to get it correct. Care and patience are a virtue here, the goal being to eventually get it properly aligned without spreading solder onto any more pins or pads and without heating the PCB or IC enough to damage them.

Once the part is in place, solder the diagonally opposite pin, then re-check the alignment under magnification as it may have moved slightly. If it has, you can reheat this second pad and gently twist the IC back into alignment. Once you're happy, proceed to solder the remaining pins without worrying too much about bridging them (it's hard to avoid). Remember to refresh that first pin you soldered.

Now spread a thin layer of flux paste along all the pins and gently press down on them with solder wick and a hot iron to suck up the excess solder. If done correctly, this will leave you with neatly soldered pins and no solder bridges. Go over all the pins once with the solder wick, then check under a magnifier for any remaining bridges. If there are any, add a dab of flux paste and go back over them with the solder wick.

With all the joints looking good, you can install the other SMD IC using the same procedure. Note that a hot-air

Table 1: Resistor Colour Codes

❑	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	1	47kΩ	yellow violet orange brown	yellow violet black red brown
❑	5	10kΩ	brown black orange brown	brown black black red brown
❑	1	1kΩ	brown black red brown	brown black black brown brown
❑	1	200Ω	red black brown brown	red black black black brown
❑	1	120Ω	brown red brown brown	brown red black black brown
❑	1	100Ω	brown black brown brown	brown black black black brown
❑	1	4.7Ω	yellow violet gold brown	yellow violet black silver brown
❑	1	3.3Ω	orange orange gold brown	orange orange black silver brown

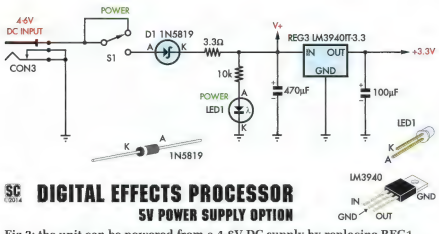


Fig.3: the unit can be powered from a 4-6V DC supply by replacing REG1 with an LM3940IT-3.3 low-dropout regulator and changing D1 to a 1N5819.

gun/toaster oven and solder paste can also be used for these ICs.

Once you've checked that the ICs are all soldered properly, follow with the SMD ceramic capacitors, using a similar procedure; ie, add solder to one pad, heat and slide the part into place, then solder the other pad and refresh the initial joint. Don't get the 10µF capacitor mixed up with the others.

You do need to be careful to wait about 10 seconds after soldering one side of a capacitor before applying solder to the other side though. The capacitors are so small that the solder joint can remain molten for quite some time. If you try to solder the opposite pad too early, the capacitor will move out of alignment and it's frustrating to re-align capacitors when this happens, especially if solder has taken to the other pad too.

So take it slowly and be careful not to short any of the adjacent IC pins when soldering the pads; the capacitors have been placed quite close for performance reasons. A fine soldering iron tip will make this easier.

Through-hole parts

Proceed now with the low-profile components such as resistors and diodes – remember to slip a ferrite bead over the 4.7Ω resistor lead before soldering it in place. It's best to check each resistor value with a DMM before fitting it as the colour bands can be difficult to read. The diodes are all the same type and all have their cathode bands facing to the top or right edge of the board.

For FB2, slip another bead over a resistor lead off-cut and then solder it to the board. You can also mount axial inductor L1 at this point. Then fit REG1 or REG3 (depending on supply voltage); bend its leads down about 6mm from its body, feed them through the holes, screw its tab to the PCB tightly

Parts List

1 double-sided PCB, coded 01110131, 148 x 80mm
1 12MHz HC-49 crystal (X1)
1 100µH axial RF inductor (L1)
2 10kΩ 9mm horizontal potentiometer (VR3,VR4)
1 5kΩ mini horizontal trimpot (VR6)
2 6.35mm PCB-mount stereo switched jack sockets (CON1,CON2) (Jaycar PS0195, Altronics P0099 or P0073)
1 10-way pin header, 2.54mm pitch (CON5)
1 5-way pin header, 2.54mm pitch (CON7) (optional)
1 PCB-mount SPDT right-angle toggle switch (S1) (Altronics S1320)
1 chassis-mount NO momentary pushbutton switch (S2)
1 4-position rotary or slide switch (S3)
1 3-way pin header, 2.54mm pitch (for S4)
1 foot switch with cable (S4, optional)
1 DC plugpack, 7.5-12V, 100mA+
1 PCB-mount switched DC socket to suit plugpack
2 4mm ferrite suppression beads
9 M3 x 6mm machine screws
1 M3 nut
4 tapped spacers
1 metal case (optional)
Light duty hook-up wire/ribbon cable

Semiconductors

1 PIC32MX470F512H-I/PT 32-bit microcontroller programmed with 0120914A.hex (IC1) (available from SILICON CHIP Online Shop)
1 WM8731SEDS 24-bit 96kHz stereo CODEC (IC3) (element14 1776264)
3 1N4004 diodes (D1-D3)
2 1N4148 diodes (D4,D5)
1 LM317T adjustable regulator (REG1) (refer to text for parts required for 5V DC operation)
1 3mm blue LED (LED1)

Capacitors

2 1000µF 25V electrolytic
6 100µF 16V electrolytic
1 22µF 16V electrolytic
1 10µF 6.3V 0805 SMD ceramic
1 1µF 50V monolithic ceramic
11 100nF 6.3V 0805 SMD ceramic
1 1nF MKT
2 33pF ceramic disc

Resistors (0.25W, 1%)

1 47kΩ	1 120Ω
5 10kΩ	1 100Ω
1 1kΩ	1 4.7Ω 0.5W 5%
1 200Ω	1 3.3Ω 0.5W 5%

Extra parts for headphone output

1 panel-mount stereo jack socket
1 10kΩ linear potentiometer, panel mount (VR7)
1 small knob to suit
2 220µF 10V electrolytic capacitors
2 47kΩ 0.25W resistors
1 3-way pin header
1 100mm length 2-core shielded cable or 3-strand ribbon cable
1 100mm length 3-strand ribbon cable

Extra parts for microphone input

1 3.5mm panel-mount stereo jack socket
1 1µF multi-layer ceramic capacitor
1 220pF ceramic capacitor
1 47kΩ 0.25W resistor
1 680Ω 0.25W resistor
1 2-way pin header
1 length shielded cable
1 length light-duty hookup wire

and then solder and trim the leads.

Horizontal trimpot VR6 can go in next, followed by the ceramic capacitors (disc and monolithic multilayer) and then pin headers CON5 and CON7, plus the one for S4. You will also have to fit CON8/CON9 if you are using those optional features. Note that CON7 is not required if you have a pre-programmed microcontroller.

Now solder the DC socket in place, followed by VR3 and VR4. Note that you could mount all these components off-board (eg, chassis mount them) and run them back to the pads via flying leads, if that suits your application. This would be the way to fit the unit into a guitar amplifier, for example.

You can then fit crystal X1 and the electrolytic capacitors, of which there are three different values (four if using the headphone outputs). As usual, the longer lead is positive and this should go in the hole marked with the '+' symbol on the overlay, ie, towards the top edge of the board.

Next, fit power switch S1 and the power LED. The latter should have its lead bent at right angles 4mm from the base of the lens and then soldered so that the centre of the lens (and thus this short lead section) is 6.5mm above the top surface of the PCB. This aligns the centre LED with the centre of the switch. When bending the leads, pay attention to the "A" and "K" markings on the PCB as the longer (anode) lead of LED1 must be soldered to the anode pad.

S1 and the power LED could also be chassis-mounted if you wish.

The PCB assembly can now be completed by soldering jack sockets CON1 and CON2 in place. You will also need to wire up a rotary or slide switch (S3) and a momentary pushbutton switch (S2) to a pin header socket, as shown in Fig.2.

If using the foot (defeat) switch, headphone or microphone options, wire them up too. We've shown the foot switch connected via a 3.5mm phono socket but you could use a 6.35mm socket or some other connector instead.

Checking it out

If you used a blank PIC32 chip, program it now. The circuit can be powered from a PICkit3 at 3.3V. In fact the whole unit will operate normally from this supply so you can test the audio signal path immediately after programming the chip. Use the firmware for the Digital Effects Processor which is named "0120914A.hex".

If you don't have a PICkit3, you will need to power the unit from a DC plugpack for testing. In this case, connect a voltmeter across the 3.3Ω resistor next to D1. Small alligator clip leads (or other test probe clips) are very useful for this purpose as you can switch the unit on while watching the meter reading and switch it off quickly should the voltage across this resistor rise too high.

Expect a reading in the range of 0.2-0.3V, depending on the exact resistor value and how you have configured the unit. Much less than 0.2V indicates that there is an open circuit somewhere while much more than 0.3V indicates a likely short circuit. If the reading is outside the expected range, switch off immediately and check for faults.

The most likely faults would be pins on the SMD chips bridged to an adjacent pin or not properly soldered to the PCB pad, followed by incorrect device orientation (primarily ICs, diodes and electrolytic capacitors) or poor/bridged through-hole solder joints.

Assuming all is OK, connect S3, set it to position 2 (no effect) and feed a signal into the input; if it's a stereo plug, the left channel will be shorted out. Connect the output to some sort of amplifier. You should hear clear, undistorted audio with no effects. You can then try out the effects to check that they operate as expected.

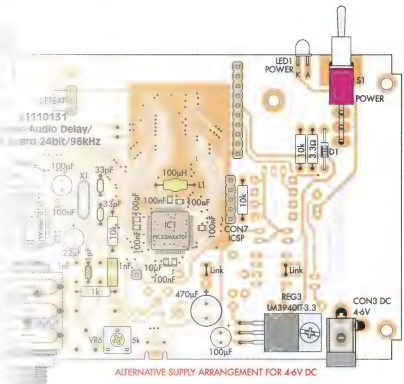


Fig.4: follow this PCB parts layout diagram to install the parts for the 5V power supply option. Note that D1 must be changed to a 1N5819 Schottky type.

Using effects

Initially, the effect for switch position #1 is echo, position #3 is reverb and position #4 is tremolo, so you can easily try these out. To adjust the parameters, hold down S2 and then rotate VR3 and/or VR4. Once you release S2, turning VR3 and VR4 will have no effect, so you can't accidentally change the settings.

To assign a different effect to one of these switch positions, select that position and then give S2 a brief press without turning either VR3 or VR4. The unit will switch to the next effect and will emit a series of 'pips' from the audio output; one pip for effect #1 (echo), two for effect #2 (reverb) and so on. If you press S2 when effect #10 (phaser) is selected, it will switch back to #1 (echo).

The settings are remembered even when power is removed; they're stored in flash memory. If you press S2 in order to adjust VR3/VR4 and then decide against it, hold S2 down for a short period before releasing it to prevent an undesired change in the selected effect. Any press longer than about half a second will not cause the selected effect to change. SC

Passive Direct Injection (DI) Box

Add this vital piece of equipment to your musician's or roadie's toolbox

Main Features

- Suitable for use with powered instruments
- No battery or power supply required
- Compact size and rugged construction
- Balanced XLR output
- 6.35mm jack socket for mono input
- 3.5mm jack socket for stereo input (mixed to mono)
- 20Hz-20kHz frequency response
- Ground lift switch

Note: not suitable for direct connection to high-impedance stringed instrument pick-ups.

Hum and noise plaguing your performance? A DI box that converts unbalanced signals from a musical instrument into a balanced output signal is the answer. This Passive DI Box performs as well as a powered unit in many applications and doesn't require batteries.

By JOHN CLARKE

DIRECT INJECTION BOXES are used to connect musical instruments into a sound system, whether they are electric, electronic or fitted with a microphone. Many such instruments have a 6.35mm (1/4-inch) 'jack' output socket whereas a PA system or mixing board will typically have XLR inputs. The term 'Direct Injection' (DI) refers to a physical (wired) connection, rather than using a microphone to pick up the instrument's sound output.

A cable with different connectors on the ends won't do the job; a DI Box is required to convert the signal from the musical instrument so that it's suitable to feed to a sound system. Specifically, the unbalanced signal from the instrument must be converted to a balanced signal for the sound system, to avoid an inordinate amount of hum injection.

Commercial passive DI boxes can be heavy and bulky and many units have extruded finned aluminium heatsink-style cases. This SILICON CHIP DI Box is compact, looks and sound good, and requires no external power or batteries.

Balanced signals

A DI box is usually connected to a musical instrument via a relatively short lead. That's because an unbalanced input is not as good at rejecting hum pick-up as the balanced output on the DI box. A balanced output lead can be quite long and is typically run to a remote sound system (eg, an amplifier or mixer).

A balanced cable has good hum rejection because it has two signal conductors, one with the original signal and the other with an inverted version of the same signal. These conductors are normally twisted together and any hum pick-up (or other interference) should be coupled into both conductors almost equally. At the far end, the signals from the two conductors are subtracted, which reinforces the original signal but cancels out any extraneous signals which may have

been picked up along the way.

Converting between unbalanced and balanced signals can be done using either electronic circuitry in an Active DI Box or by using a transformer in a Passive DI Box. Active DI boxes have the advantage that their input impedance can be very high (over 1MΩ), making them suitable for the pick-ups used in guitars, violins and other stringed instruments. Their disadvantage is that if powered from a battery, the battery ultimately goes flat, causing distortion in the sound. And they often stop working at the most crucial time – right in the middle of a session!

This Passive DI Box does not need power and can be relied on to perform faultlessly with no maintenance. It does not have such a high input impedance but it is suitable for many instruments that have a low output impedance. This includes electronic keyboards, computer audio outputs and A/V system sound outputs. In the case of stringed instruments, it is increasingly common for these to include an in-built preamplifier for the pick-up and this can easily drive a Passive DI Box.

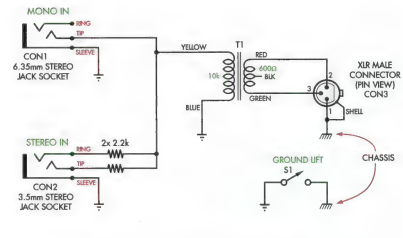
Another feature of a DI Box is that it provides impedance matching and has a reasonably high input impedance that's suitable for powered instrument signals. The output impedance of the DI box is much lower, at 600Ω or less, and this is better for driving balanced leads. A lower output impedance further reduces the effects of hum and noise pick-up.

Hum loops

As with any sound system, the way that the cable shielding is grounded can have a huge impact on the amount of hum induced in the leads and in the sound output.

Unbalanced leads need to have the shield earthed to minimise the hum pick-up. That normally means that in a DI Box, the shield of the unbalanced lead will be connected to the shield of the balanced lead which is ultimately grounded at the mixer (or sound system, etc).

However, some unbalanced leads are already grounded at the signal source and so this connection will produce an earth loop due to circulating currents in the shield wire, thus injecting hum. As a result, many DI Boxes include a 'ground lift' switch. This is used to disconnect the two shields when they are separately earthed.



SC 2014 PASSIVE DIRECT INJECTION (DI) BOX

Fig.1: the circuit uses just two input jack sockets (one for mono signals and one for stereo), a 10kΩ:600Ω transformer, an XLR output connector and a rocker switch to provide ground lift. No power supply is required.

DI Boxes can carry very low signal levels and in use, are often surrounded by many other leads. Some of these nearby leads will likely carry mains power. Thus, a DI Box must be well shielded from 50Hz fields. It must also be robust as it will typically be on the floor and is liable to be trodden on, kicked or tripped over.

Connectors

Our Passive DI (Direct Injection) Box is built into a metal diecast case with both 6.35mm and 3.5mm jack sockets at one end and a male XLR connector at the other. The input impedance is 10kΩ for the 6.35mm jack socket and about 3kΩ for each input of the 3.5mm socket. This is sufficiently high for virtually all powered instruments. That includes keyboards and stringed instruments such as guitars that have an internal preamplifier. **It is not suitable for high impedance pick-ups unless these are connected via a preamplifier or effects box.**

The 3.5mm jack socket can be used to connect a computer, MP3 player or other stereo source. The Passive DI Box mixes the incoming stereo signal into mono.

Performance

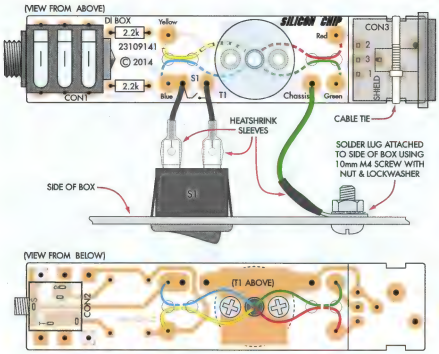
The performance of the SILICON CHIP Passive DI Box is impressive. It easily outperformed one commercially available unit we compared it against, both in terms of audio sound quality and frequency response. While the frequency response of the commercial unit was very restricted in the bass region (-3dB at 250Hz, -6dB at 125Hz and more than -12dB at 60Hz!), our unit could pass signals well below 20Hz without any appreciable attenuation.

In addition, the unit does not add any noticeable noise to the signal. Our tests for signal-to-noise ratio do not do the unit justice as the tests results are below the noise floor of our Audio Precision measuring equipment. The distortion is very low and is typically below 0.02% for a 1V signal above 100Hz. It has even lower distortion with lower signal levels.

The exceptional sound quality from the Passive DI Box is due to use of a high-quality audio transformer from Altronics. It incorporates a Mu metal shield for extra low noise and hum. Several musicians who tested our Passive DI Box remarked that it has better quality sound than many commercial units.

Circuit details

Fig.1 shows the complete circuit, which is based around the Altronics M-0705 transformer with a 10kΩ primary and 600Ω secondary. 6.35mm stereo jack socket CON1 is used for mono input signals while 3.5mm jack socket CON2 is used for stereo signals. The tip (left) and ring (right) signals from the latter are mixed by a pair of 2.2kΩ resistors and fed to T1's primary. Since CON1 is for mono signals, only its tip contact is connected and this also goes to T1's primary winding.



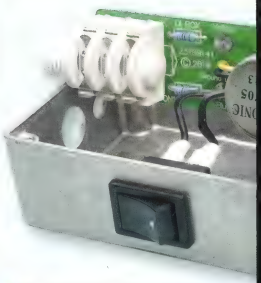


Fig.2: install the parts on the PCB and complete the wiring as shown in this diagram and the accompanying photograph.

The other end of the primary winding connects to the input signal ground, ie, the two connector sleeves. The balanced output signal appears across the 600Ω secondary of T1, so pins 2 & 3 of XLR plug CON3 are connected directly across this winding. The centre tap of the secondary winding isn't used so the output 'floats'.

Pin 1 of the XLR connector is the ground pin and this is connected to the DI Box case and the shell of the plug housing. Even though the XLR socket is a plastic connector, there is a metal contact that connects to provide shielding for the XLR plug when it is inserted into this socket.

The input and output grounds are joined only by switch S1. Opening this switch provides the ground lift. Normally S1 is left closed unless there is a hum loop.

Construction

The SILICON CHIP Passive Direct Injection Box is assembled onto a double-sided PCB coded 23111141 and measuring 105 x 24mm. This fits neatly into a 111 x 60 x 30mm diecast aluminium box (with a little coaxing).

Fig.2 shows the parts layout on the PCB and the external wiring. The 3.5mm jack socket is installed on the underside of the PCB while the 6.35mm jack socket, two resistors, transformer T1 and the XLR plug all mount on the top side. Solder the 3.5mm jack socket first because when the 6.35mm jack socket is installed, the 3.5mm socket pins will be inaccessible. Both sockets should be pushed as far down onto the PCB as they will go.

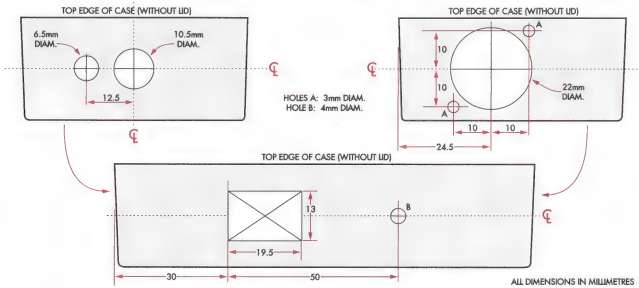


Fig.3: this diagram can be copied and used the three sections cut out and used as drilling templates for the metal case. It can also be downloaded (in PDF format) from the SILICON CHIP website and printed out.

Specifications

Input signal handling: 2V RMS
Input impedance: ~3kΩ (stereo source), 10kΩ (mono source)
Output impedance: 600Ω
Output level: typically 250mV RMS (balanced) for a 1V RMS mono input
Frequency response: ±0.5dB, 20Hz-20kHz
Signal-to-noise ratio: -98dB unweighted (22Hz-22kHz); -101dB A-weighted, both with respect to 1V RMS input
Total harmonic distortion: <0.02%, 100Hz-20kHz (0.1% @ 30Hz), 1V RMS input
Phase shift between input & output: 7° at 20Hz, 3° at 100Hz, ~0° above 1kHz
Dimensions: 115 x 65 x 33mm **Mass:** 175g

Parts List: Passive DI Box

1 double-sided PCB, code 23111141, 105 x 24mm
1 panel label, 51 x 102mm
1 diecast box, 111 x 60 x 30mm (Jaycar HB-5064 or Altronics H 0432)
1 6.35mm stereo switched PCB-mount jack socket (CON1) (Jaycar PS-0190, Altronics P 0073 or PA0073)
1 3.5mm stereo PCB-mount jack socket (CON2) (Jaycar PS-0133, Altronics P 0092)
1 right-angle PCB-mount XLR male connector (CON3) (Altronics P 0874)
1 10kΩ to 600Ω Mu metal shielded transformer (T1) (Altronics M 0705)
1 SPST rocker switch (S1) (Jaycar SK-0984, Altronics S 3210)
2 2.2kΩ 0.25W or 0.5W 1% resistors
2 M3 x 6mm pan head machine screws
2 M3 x 10mm countersink head machine screws
2 3mm star washers
1 M4 x 10mm countersink head machine screw
4 M4 x 10mm Nylon pan head screws (optional, for feet)
1 M4 nut
1 4mm star washer
1 solder lug
1 60mm length of green medium duty (24 x 0.2mm) hookup wire
1 120mm length of black medium duty (24 x 0.2mm) hookup wire
1 100mm cable tie
1 100mm length of 6mm heatshrink tubing

With the sockets fitted, follow with the 2.2kΩ resistors. The transformer is then secured to the PCB using M3 x 6mm screws and star washers. The screws (fitted with the washers) are fed up from the underside of the PCB and go into M3 tapped holes on either side of the transformer.

That done, feed the transformer wires up through the adjacent holes in the PCB (see Fig.2), then back down again and solder them to the indicated pads (ie, with the solder joints on the top). The wires are colour coded and must be connected as shown to correctly preserve the signal phase (ie, in-phase output to XLR pin 2 [hot]). We have marked the colours of the wires that correspond to the 10kΩ and 600Ω windings on both the PCB itself and the parts layout diagram.

The leads for the switch and chassis earth can now be stripped and soldered to the PCB. Solder the other end of the earth wire to the solder lug. The soldered section of this terminal should be covered with heatshrink tubing, to prevent the lead from breaking at the solder joint.

The XLR socket is held down using a cable tie that straps around the body and around the PCB at the recessed cut-outs on either side. The positioning of the cable tie joiner is important. It must be positioned as shown in the photos, so it does not foul the case or lid.

The case is used upside-down, with the lid as the base. Note that the Altronics version has a flanged lid; if you don't want the flanges, it's just a matter of cutting them off.

Cut-out and drilling templates are provided for the various holes required in the base – see Fig.3. These templates can also be downloaded (no charge) from the SILICON CHIP website and printed out (browse to www.siliconchip.com.au and then click 'Shop', 'by Year/Month' and select October/2014).

The diecast aluminium is very easy to drill and file. The 6.5mm and 10.5mm-diameter holes are best made by first drilling small pilot holes, then carefully enlarging them to size using a tapered reamer. By contrast, the 22mm hole for the XLR connector is best made using a 22mm speed bore drill. Alternatively, it can be made by drilling around the inside perimeter with a small drill, then knocking out the centre piece and filing to shape. This same method can be used for the rectangular switch cut-out

You also have to drill holes for the XLR mounting screws and the earth screw. If using countersunk screws (a good idea), countersink the holes to suit. The mounting holes on the XLR connector are untapped however threads can be formed by simply forcing the M3 screws into the holes.

Once all the holes have been drilled, cover the threaded ferrule on the 3.5mm socket with a short length of 6mm-diameter heatshrink tubing. This is necessary to insulate it from

This view shows the PCB assembly prior to installation in the case.

the case. The heatshrink tubing must be shrunk down so that it cannot fall off and it should later fit snugly into the 6.5mm hole for this socket.

We tapped the box corner holes to an M4 thread so that M4 Nylon screws could be used to secure the lid. The heads of these screws then act as feet. Alternatively, you can skip this step and use the original metal screws. You can then elect to either not have feet or you could attach separate screw-on/stick-on feet to the lid (although these may not last long if the unit is treated roughly).

Final assembly

The PCB assembly is inserted into the box in a special way. First, the 6.35mm and 3.5mm jack socket ferrules are inserted into their respective holes. The PCB is then bent in the middle by pushing down on the transformer and pushing the XLR connector inwards. This then allows the XLR socket to be slid into the box, after which the PCB is released so the socket fits into its 22mm-diameter hole. Fig.5 shows the details.

If necessary, the PCB assembly can be removed from the case using the reverse procedure.

The rocker switch can now be clipped into position and the earth lug secured to the side of the case using an M4 x 10mm screw, star washer and nut. Finally, complete the wiring to the switch lugs and secure the XLR socket to the case using two M3 x 10mm countersink head screws. As with the earth lug connection, it's a good idea to fit heatshrink tubing over the connections to the switch lugs to prevent the leads from breaking at the solder joints.

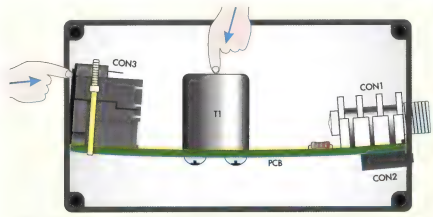


Fig.5: the PCB is installed in the case by inserting the jack socket ferrules into their holes at one end and then bending the PCB by pushing against transformer T1 and the XLR socket (CON3) as shown here.

Fig.4: the full-size front panel label. It's also available (in PDF format) from the SILICON CHIP website.

Testing

The Passive DI Box is tested by feeding in a signal from an instrument or signal generator and measuring the output across pins 2 & 3 of the XLR socket.

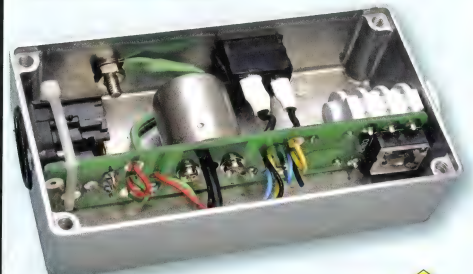
To do this, set your multimeter to read 'mV AC', plug the instrument or generator into the DI box and play the instrument. You should get a signal reading of about 250mV on the meter for an input of around 1V RMS.

If that checks out, set your multimeter to read ohms and connect it between the ground (sleeve) connection of the instrument's jack plug in the DI Box and pin 1 of the XLR plug. Now check that this connection can be opened and closed using switch S1.

Assuming it all works as expected, you can now fit the lid and affix the front-panel label to the base (not the lid). This label can be downloaded from the SILICON CHIP website in PDF format and printed out on a colour printer.

You have several options here. First, you can just use paper or photo-paper

Above: once the PCB is in the case, it's secured by fitting a nut to the 6.35mm jack socket at one end and two M3 x 6mm countersink-head machine screws to the XLR socket at the other end.



It's a good idea to fit heatshrink tubing over the wiring connections to the switch and the earth lug to prevent the wires breaking at the solder joints.

and affix the resulting label using a suitable glue or neutral cure silicone. However, this type of label is easily damaged.

Alternatively, for a more rugged label, print a mirror image label onto clear overhead projector film (be sure to use a film that's suitable for your printer). This is then attached using clear or coloured silicone sealant, with the image on the inside.

Another approach is to print onto an A4-size synthetic 'Dataflex' sticky label if using an inkjet printer, or onto a 'Datapol' sticky label if using a laser printer. This can then be trimmed to size and affixed to the base of the case using the label's self-adhesive backing.

Dataflex and Datapol labels are available from www.blanklabels.com.au and sample sheets are available on request to test in your printer – see panel.

Dataflex & Datapol Labels

(1) For Dataflex labels, go to http://www.blanklabels.com.au/index.php?main_page=product_info&cPath=49_60&products_id=335

(2) For Datapol labels go to http://www.blanklabels.com.au/index.php?main_page=product_info&cPath=49_55&products_id=326

Your Passive DI Box is now ready for use. Just remember that you can't plug the high-impedance output from an electric guitar directly into it. SC

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CIRCUIT NOTEBOOK

Interesting circuit ideas which we have checked but not built and tested. Contributions will be paid for at standard rates. All submissions should include full name, address & phone number.

PICAXE-based bistro paging system

This bistro paging system was inspired by the various pagers handed out in clubs and restaurants for meal and drinks orders. The project has a base station and up to 99 portable 'guest pagers'. The base station provides a 7-segment display and keypad to call the guest pagers, each of which has a buzzer and a row of six blue LEDs to alert the guests. This easy-to-build design does not need rechargeable batteries or a pager-style vibrator.

The system communicates in the UHF band using pre-built 433MHz wireless modules. It transmits eight bytes of Manchester encoded data, containing a 6-byte 'system code' common to all the pagers and also a 2-byte 'pager code' identifying individual pagers. The default system code is 123456 while each guest pager requires a unique pager code in the range 00 to 99. Check the program notes on how to enter your own codes.

The base station (Fig.1) includes a PICAXE-20M2 (IC1) and a ZW-3100 433MHz transmitter module. The keypad connects to analog input pins 15-17 of IC1. The program is able to detect individual keys using the voltage levels present on the resistive divider feeding the keypad.

The 2-digit 7-segment display is multiplexed using transistors Q1 & Q2 to drive the common cathode pins while the anode pins are driven by the micro via seven 100Ω current-limiting resistors. The base station runs on 5V DC using a 7805 regulator and a 9V or 12V DC plugpack,

You call guest pagers using the keypad. Press the 'star' key to blank the display then enter a 2-digit pager number followed by the hash key to transmit the 'pager code'. The wireless transmission turns on output pin 14 of IC1 to power the Tx module's Vcc pin while output pin 13 sends the Manchester encoded data to the Tx module's data pin.

Each key press is accompanied by a beep from a 3.3kHz piezo buzzer which is driven by pin 18 of IC1.

The data is transmitted using the 'rfout' command and received using the 'rfin' command.

Each guest pager includes a PICAXE-14M2 (IC2) and a ZW-3102 receiver module (Fig.2). The Manchester encoded data is received by the Rx module and fed to pin 4 of IC2. IC2's outputs drive LED1-LED6 (the six blue LEDs) and also a 400Hz buzzer. The alarm sequence sounds the buzzer six times while also lighting the LEDs one after the other in a cycle lasting 40 seconds.

To test pagers, a jumper on LK1 gives an 8-second cycle. The pagers are powered from four alkaline AA cells.

Ian Robertson is this month's winner of a $150 gift voucher from Hare & Forbes

Before handing out each guest pager you momentarily operate reed relay RLY1 with a magnet to turn the pager on. Orientate the magnet to assist rather than cancel the relay coil magnetism. To confirm the pager is on, LED1 and LED6 will flash and the buzzer will beep twice. The 'wait' indicator (LED7) will illuminate and output pin 7 of IC2 will hold relay RLY1 on, only dropping out after the pager is called and the alarm sequence ends.

The wireless transmitter and receiver modules will each require a suitable antenna, the simplest being a length of stiff insulated hook-up wire 170mm long. Depending on the enclosure dimensions, the antenna wire may be straight or coiled into a spiral.

The microcontrollers have ICSP headers for programming. Use a PICAXE serial or USB cable to download 'bistrobase_20m2.bas' into IC1 and 'bistropager_14m2.bas' into IC2. When programming the guest pagers, place a magnet next to the reed relay to power IC2.

The software is available on the SILICON CHIP website.

Ian Robertson, Engadine, NSW.

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As you can see, we pay $$$ for contributions to Circuit Notebook. Each month the BEST contribution *(at the sole discretion of the editor)* receives a **$150 gift voucher from Hare&Forbes Machineryhouse**. That's yours to spend at Hare&Forbes Machineryhouse as you see fit - buy some tools you've always wanted, or put it towards that big purchase you've never been able to afford!

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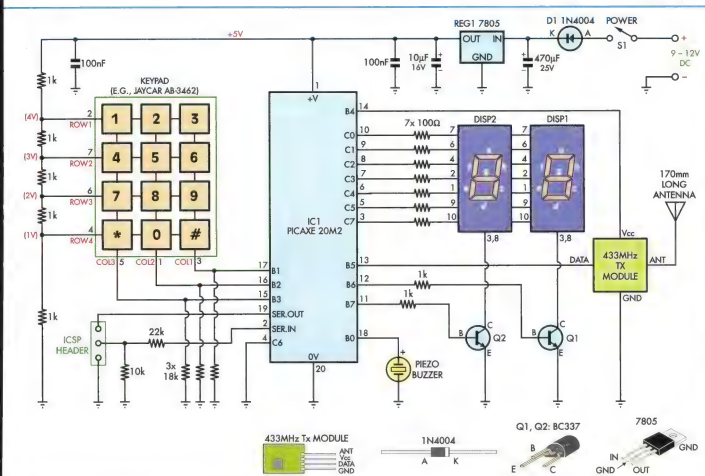

Fig.1: the base station uses a PICAXE 20M2 microcontroller (IC1), a keypad, two 7-segment displays and a 433MHz transmitter module to call up to 99 guest pagers. The unit is powered from a 9-12V DC plugpack.

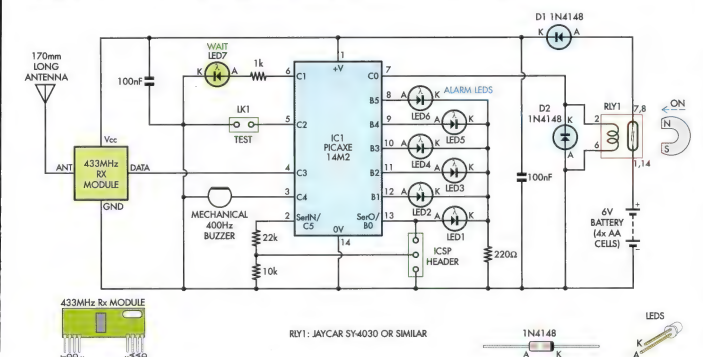

Fig.2: a 433MHz receiver module in each guest pager picks up the signal from the base station and feeds the data to a PICAXE 14M2. This decodes the data and drives blue LEDs LD1-LD6 and sounds a buzzer. Reed switch RLY1 is used to turn the unit on. Power comes from four 1.5V AA cells.

Micromite GPS dual clock with 7-day alarm

I was so impressed with Geoff Graham's article on using a 28-pin Micromite with a GPS unit to create a simple GPS-Controlled Clock (Silicon Chip, May 2014) that I thought it deserved to be expanded to a full-blown clock with some additional bells and whistles.

A GPS clock has a couple of great advantages. First, its accuracy; it will never gain or lose time. Secondly, it will always recover from a power outage with the correct time. It will never require resetting.

So what extra features would you want over Geoff's original circuit? Well, I consider the 16x2 LCD an unsuitable display for a real clock. A practical clock has to be readable from the other side of the room, so I decided that four 25mm 7-segment LED displays (RS Cat. 235-8957) would be more suitable for displaying the time. These units use two diodes per segment, so smaller units using one diode per segment would not be direct replacements.

I decided to keep the LCD as well, because it is capable of displaying the date as well as any other details you might want to extract from the GPS signal. Also, if the LCD is an Arduino 16x2 Keypad Shield, you can take advantage of the six inbuilt control buttons to perform alarm-setting functions.

The alarm is a 7-day type where you can set different ON/OFF times for each day. When the ON time has occurred, a relay will switch mains power to a GPO and when the OFF time is reached, power will be removed. Once the alarm information has been entered it is stored in non-volatile memory so that after a power outage the clock will resume not only with the correct time but with all the alarm settings as well.

The circuit diagram (Fig.1) shows the EM408 GPS unit connected to pins 21 & 22 and the console connected to pins 11 & 12 of the Micromite. This is the basic GPS clock which was fully described in the May 2014 issue. Note that the EM408 should be the TTL version rather than the RS232 version (see Geoff Graham's website for an explanation of the differences).

If you do use the RS232 version it will have to be connected to the Maximite via an RS232-to-TTL converter such as described in the Circuit Notebook pages of the August 2014 issue or you could use the simpler circuit in July 2014. In the latter case, you would also need to change the program line:

Open "COM1:4800" As #1 to
Open "COM1:4800,INV" As #1

The four 7-segment LED displays are driven by IC1, a BCD to 7-segment decoder. IC1 gets its BCD input from pins 15-17 of the Micromite. The four displays are multiplexed using a 74HC238 wired as a 2-to-4 multiplexer. By using this chip, only two output pins (23 & 24) of the Micromite are needed rather than four; this project uses all available Micromite I/O pins. The decimal point on the hours display is driven by pin 3 of the Micromite and toggles every second to create a 'heartbeat' for the clock.

Switch S1 is the ALARM ON/OFF switch. When the alarm is set, the decimal point on the minutes display is illuminated and the set condition is sensed by pin 26 on the Micromite.

The use of the Arduino 16x2 keypad shield with a MiniMaximite was explained in an earlier Circuit Notebook article (Silicon Chip, March 2014). Its connection to the Micromite follows the same pattern. Pins 4-7 of the Micromite control data lines D4-D7 of the LCD, while the RS and EN lines are connected to pins 9 and 10 respectively of the Micromite.

The LCD has its own inbuilt contrast control. The LCD shield is a 5V device and suitable power connections of 5V and 0V are connected to the shield where shown.

The reset button will cause the LCD to re-initialise. I found that the LCD would sometimes revert to printing rubbish characters, probably due to some form of interference. Without the reset button, the only way to restore normal LCD operation is to switch the device off and on. The reset button is enabled by connecting the reset pin on the LCD to pin 2 of the Micromite which is pulled high to 3.3V via an 8.2kΩ resistor as shown.

All the other buttons – EXIT, UP, DOWN, ITEM, and MEMORY – are activated through the analog LCD pin, A0, which connects to pin 25 of the Micromite. Ra, a 5.6kΩ resistor, grounds this line. Ra combines with internal resistors (not shown) in the LCD to form a complex voltage divider. It is essential that Ra is of the correct value and some initial experimentation may be required.

The correct value for Ra is such that with no button pressed, pin A0 is as close to 3.3V as possible without exceeding it. This should be done before any connections are made to the Micromite. Simply connect the power pins of the LCD to +5V and 0V and connect a 5.6kΩ resistor from the A0 pin to 0V. Then use an accurate voltmeter to measure the voltage on the A0 pin with no button pressed. Change the 5.6kΩ resistor if necessary to get the desired voltage at pin A0 (≤ 3.3V).

There must be considerable variation in the LCD construction because in one case Ra needed to be 5.6kΩ whereas in another it was 3.9kΩ. Unfortunately, each value will present slightly different voltage levels to the analog input.

Next, press each button in turn and record the voltage at A0 for each. Draw up a table as shown in Table 1 (ie, substitute your measurements in the "A0 Voltage" row):

The "Upper Limit" and "Lower Limit" rows show the values used in

continued on page 104

Table 1

	No Button	Memory	Item	Down	Up	Exit
Upper Limit		2.84	2.09	1.47	0.87	0.27
A0 Voltage	3.21	2.53	1.85	1.29	0.61	0
Lower Limit		2.09	1.47	0.87	0.27	0

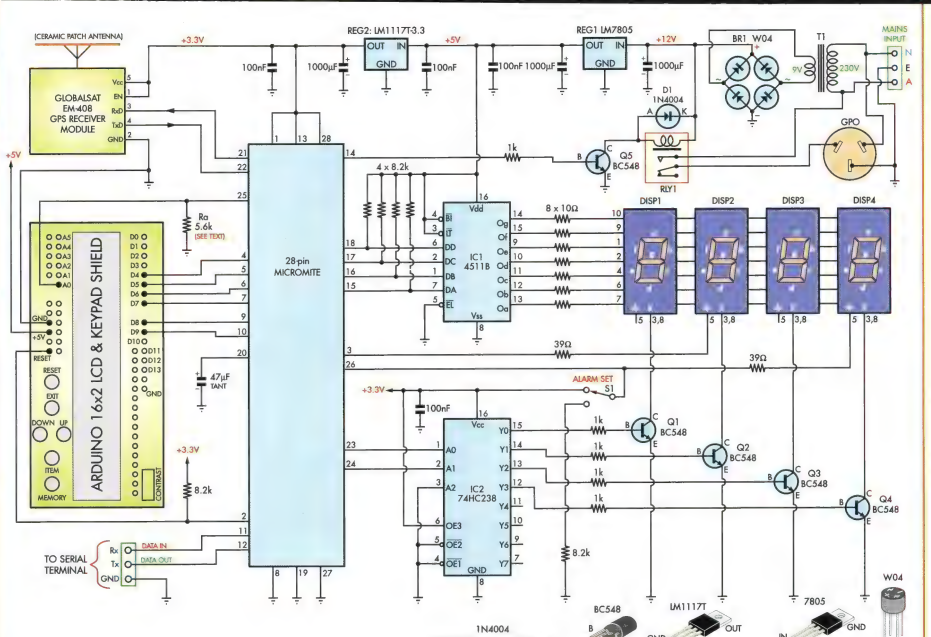

Fig.1: the circuit is based on the GPS-Controlled Clock described in May 2014 but has been considerably expanded to use an Arduino 16x2 LCD & Keypad Shield and four 7-segment LED displays. A 7-day alarm is also included, with provision to switch mains power to a GPO.

USB-powered mini spectrum analysers based on SDR technology are evolving fast. The Signal Hound USB-SA44B shows how rapidly this technology is developing – demonstrating a performance that compares very well indeed with that of high-end self contained analysers, for a fraction of their price.

When I reviewed the Triarchy TSG5G35 USB 'dongle' spectrum analyser for the January 2014 issue of SILICON CHIP, I was impressed by the level of performance it provided – especially considering its tiny price.

It did have a few shortcomings, particularly if you compared it with self-contained analysers like the Gratten GA4063 (SILICON CHIP November 2013). But it still seemed likely to have plenty of practical applications.

So I wasn't really expecting much when the opportunity came a few weeks ago to review another SDR-based USB spectrum analyser, the Signal Hound USB-SA44B.

Boy, was I wrong!

Not long after the review sample arrived I installed its accompanying software on a PC running Windows 7 Pro (64bit) and started to explore the capabilities of both the hardware and its software.

And the more I explored, the more impressed I became. . .

In fact I found that it's much more than 'yet another USB mini spectrum analyser based on SDR (software-defined radio) technology' – more an example of where this technology is

Front (above) and rear (right) panels of the Signal Hound USB-SA44B, just a bit larger than life size. There are no controls as such – they're all taken care of via the supplied software.

really headed. But let's start at the beginning.

The USB-SA44B comes from a company in the USA. Originally it was called Test Equipment Plus or 'TEP', which began operation in 1996 refurbishing and reselling used test equipment.

In 2006 they began designing and manufacturing colour LCD kits for use in refurbishing older CRT-based HP spectrum analysers for which the CRTs were no longer available.

This was so successful that they expanded their capabilities to become a comprehensive repair service for HP/Agilent spectrum analysers, oscilloscopes and signal generators.

In 2009 they decided to design a compact, lightweight and inexpensive spectrum analyser of their own. This appeared in February 2010 as the Signal Hound USB-SA44, which apparently sold like 'hot cakes'.

Before long they not only came up with an improved model (the USB-SA44B, which we're reviewing here) but also renamed the company itself as Signal Hound in April this year.

The TEP side of the business is still going strongly though, repairing HP/Agilent (and I presume the newest incarnation, Keysight Technologies) test equipment.

Encouraged by the success of the USB-SA44/B they've also produced a higher performance USB 3.0 based spectrum analyser, the BB60.

Despite its higher price, the BB60A sold out very quickly and Signal Hound will soon be releasing a production run of a significantly improved BB60C model.

So that's an idea of where the USB-SA44B comes from. By the way in Australia and New Zealand, Signal Hound products like the USB-SA44B are distributed by Silvertone Electron-

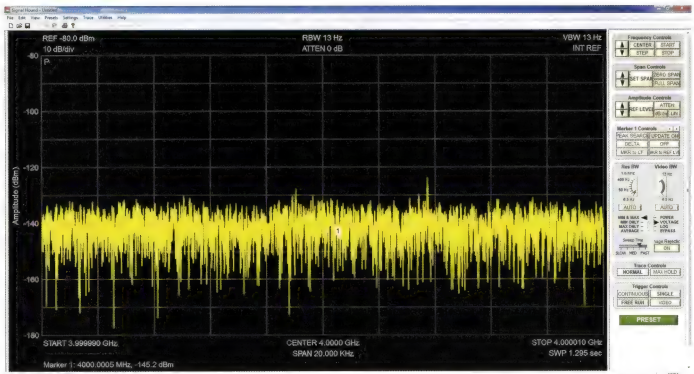

Fig.1: A screen grab showing the SA44B's DANL (displayed average noise level) at 4.0GHz with its input terminated in 50Ω. It shows a DANL of -140dBm, with very occasional spikes reaching about -124dBm. Note the control panel at right.

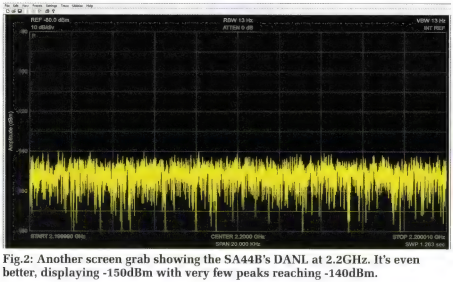

Fig.2: Another screen grab showing the SA44B's DANL at 2.2GHz. It's even better, displaying -150dBm with very few peaks reaching -140dBm.

ics, now based in Wagga Wagga, NSW. You'll find their website at www.silvertone.com.au

So let's look more closely at the USB-SA44B analyser itself. As you can see from the photo it's not as tiny as a dongle but nevertheless quite compact. The case is based on an aluminium extrusion, measuring 77 x 27mm and with a length of 167mm (not counting the input and output connectors at each end). It weighs just on 290g.

At the input end there's an SMA socket in the centre, with a busy/ready LED visible through a small window on the left.

Then at the output end there's a USB type B socket in the centre for connection back to your PC/laptop/tablet, plus a BNC socket on either side.

One of these is for feeding in an external 10MHz reference if you need higher frequency accuracy than is provided by the internal TCXO (temperature compensated crystal oscillator), while the other is for a number of utility purposes – some associated with the matching Signal Hound USB-TG44A tracking generator (available separately).

Inside the box . . .

You'll find an advanced narrowband SDR receiving system tuning over the range from 1Hz to 4.4GHz, (yes, you read that correctly!) made up from the following elements:

1. A programmable input attenuator with four ranges (0dB, -5dB, -10dB and -15dB).

2. A wideband RF preamplifier which can be switched in to achieve higher sensitivity and a lower noise floor. (The preamp can only be used for frequencies above 500kHz.)

3. A pair of mixers, where the incoming signals are mixed with higher and lower frequency local oscillator signals to allow image cancellation.

4. The two IF signals then pass through dual IF amplifier/filters, before passing to the 'IF to bits' digital receiver section, where they are processed by quadrature I/Q digital samplers to produce a 2MB/s output data stream. This is then conveyed to the PC via the USB 2.0 cable.

The output data stream from the hardware box is processed and analysed by the Signal Hound software, to produce the analyser's output display and measurements.

The software also controls the operation of the hardware, becoming the analyser's 'front panel'.

Software & manual on CD

The USB-SA44B comes with a CD-ROM containing both its matching driver and control software and the User Manual as a PDF file, plus a 1.8m-long USB cable.

An optional accessory kit, comprising a 20dB SMA/SMA fixed attenuator,

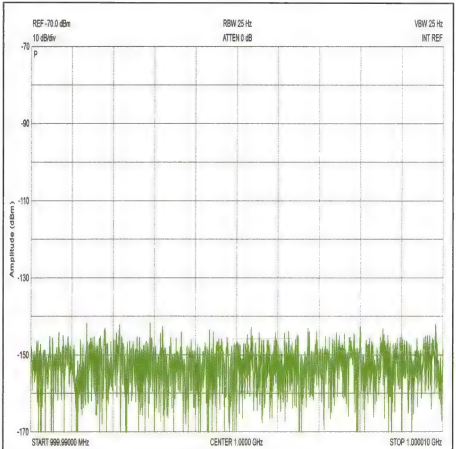

Fig.3: A printout from the SA44B's control software this time, showing its DANL or 'noise floor' at 1GHz to be a bit below -150dBm. Just about all of the analyser settings are printed out as well.

an SMA/BNC adaptor and an SMA/SMA DC blocking adaptor, is available separately.

The latter would be especially useful because the SA-44B's input circuit cannot cope with DC voltages greater than ±0.2V.

I should also mention that the software supplied on the CD-ROM is able to control the optional TG44A tracking generator as well as the SA44B.

The basic specification for the SA44B shown in the panel at right gives a good idea of the performance delivered by this very nicely integrated hardware and software combination. It compares very favourably with analysers costing many times its price (which is $AU1198.70 plus GST in Australia and NZ).

What I found

The first thing I did when the SA44B arrived was to print out the User Manual (old-fashioned, I know but I do prefer to read a 'hard copy'), and then read it carefully before proceeding. This seems to be very well written and informative.

I then realised that although I'd planned to install the SA44B's control software on my old 'workhorse' Windows XP machine near my workbench, this wouldn't be a good idea because the SA44B control software needs to link up to Signal Hound's website when it initially starts up, to download a special temperature correction file.

I had to disconnect the XP machine from the network and internet when Microsoft stopped supporting XP earlier in the year, so this wouldn't be feasible. As a result, I had to install the software on my main machine running Windows 7 Pro (64-bit) – which is connected to the internet, of course.

Installing the USB drivers and control software for the SA44B turned out to be very quick and painless. I was soon familiar with the SA44B's GUI and it gave every evidence of being well written and quite intuitive to use.

It did take a little while to get the hang of adjusting one or two of the controls on the 'front panel' running down the right-hand side of the screen but there were no major hassles.

Then I spent an interesting couple of hours running a variety of tests on the SA44B.

But before I discuss the results of this testing, I should note that although the SA44B control and display software does not allow you to directly print out any of your analyser displays: it only prints out the contents of the display window – not the control panel alongside.

It even allows you to reverse these printouts so they're dark on a white background, to save printer ink or toner.

And the display printout does contain pretty well all the information you'd normally need – like the start,

Basic Specification – Signal Hound USB-SA44B

Frequency Range:		1Hz to 4.4GHz
Span Modes:	*Either or*	Centre Frequency + Span Start + Stop Frequencies
Maximum Span:		4.4GHz
Minimum Span:		10Hz, or Zero Span
Internal Frequency Reference Accuracy:		±1ppm
Frequency Readout and Marker Accuracy:		reference error ±1 sample
Resolution Bandwidth (RBW):		0.1Hz to 250kHz
Amplitude Range: *Input level for 1dB gain compression with preamp off, attenuator set for -15dB:*		+16dBm typical, 1Hz-150MHz +19dBm typical, 150MHz-4.4GHz
Displayed Average Noise Level (DANL):		*(preamp off)* *(preamp on)*
(with 0dB input attenuation, 1Hz RBW [ie, noise floor])	10Hz:	-124dBm
	100Hz - 10kHz:	-130dBm
	10kHz - 500kHz:	-142dBm
	500kHz - 10MHz:	-142dBm -153dBm
	10MHz - 100MHz:	-148dBm -161dBm
	100MHz - 1GHz:	-144dBm -158dBm
	1GHz - 2.6GHz:	-139dBm -151dBm
	2.6GHz - 3.3GHz:	-135dBm -151dBm
	3.3GHz - 4.4GHz	-128dBm -134dBm
Absolute Accuracy (*Reference level <=0dBm*):		±1.5dB
Absolute Accuracy (*0dBm < Ref Level <+10dBm*):		±2.0dB
Relative Accuracy (*Ref Level <= 0dBm*):		±0.25dB
Maximum Safe Input Level (*15dB attenuation, preamp off*):		+20dBm
Maximum DC voltage input:		< ±0.2V, absolute
Residual Responses (*input terminated, span <= 10kHz, 0dB attenuation, preamp on*):		< -80dBm

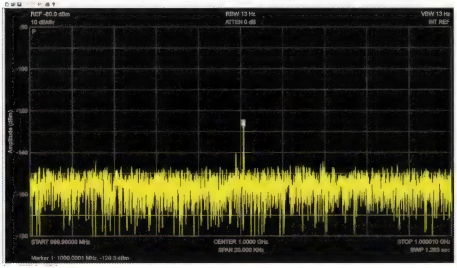

Fig.4: this shows the SA44B capturing the output of a Gratten GA-1484B signal generator at 1.0GHz and with a level of -127dBm (100nV at 50Ω). The carrier spike measures -128.3dBm, showing the cable loss as 1.3dBm.

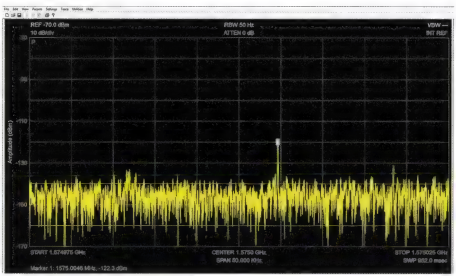

Fig.5: this one's taken with a tiny whip antenna connected to the SA44B input, scanning in the vicinity of 1575GHz. There's a small spike of -122.3dBm at 1575MHz, presumably from a GPS satellite passing nearby.

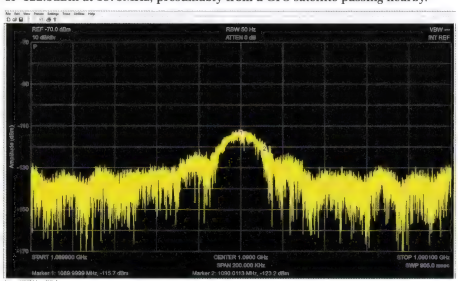

Fig.6: finally, a scan centred on 1090MHz with the SA44B connected to an external VHF-UHF discone antenna. It appears to be an ADSB squitter from a passing commercial aircraft.

centre, span and stop frequencies, the reference level, the resolution bandwidth (RBW) and video display bandwidth (VBW), the attenuator setting, whether or not the preamp is switched in, the sweep time and so on. But there seems to be no provision to print out the control panel as well.

What I had to do in order to provide the full screen grabs you see in this review was resort to the old trick of pressing the 'Print Scrn' key on the keyboard when I wanted to capture a grab and then switch to Photoshop to paste the grab in from the Windows 'clipboard', after which I could save it as a JPEG file.

Then I had to switch back to Signal Hound, in order to continue testing.

It's a bit clumsy and it would be good if Signal Hound gave you an option of saving and/or printing the entire screen.

OK then, let's look at the test results. Overall, the SA44B meets its specs with flying colours. For example, Fig.1 shows its noise floor at 4.000GHz, with the input terminated in a 50Ω wideband SMA termination, a sweep span of 20kHz, a reference level of -80dBm, an RBW of 13Hz, 0dB of input attenuation and the SA44B's preamp switched in.

As you can see its DANL (Displayed Average Noise Level) is very close to -140dBm, with only the occasional noise peak reaching about -124dBm. And the DANL figures at lower frequencies were even better. For example at 2.2GHz I measured a figure of -150dBm, with only a very few noise peaks reaching -140dBm (see Fig.2), while at 1.5GHz and below it was slightly better again (see Fig.3).

When I tried using the SA44B to look at the output of my Gratten GA-1484B signal generator at a frequency of 1.000GHz and with the output level set to -127dBm (100nV at 50Ω), I achieved the display shown in Fig.4.

As you can see it shows the signal peak as having a level of -128.3dBm, which is pretty good when you consider I had connected the two together with a 1m long SMA-SMA cable made from RG-213 coax, with a loss of about 1.3dBm.

(When I substituted a 3m long RG-213 cable, the SA44B showed a further drop of very close to 2.6dBm.)

Next I tried connecting a tiny whip antenna to the input of the SA44B, placing the antenna right in the window of my office.

Then I did a scan centred on 1.575GHz, to see if I could pick up any signals from passing GPS satellites. Fig.5 shows the result: I found a peak of -122.3dBm at 1575.0046MHz, according to the SA44B.

Finally, Fig.6 shows the result of a further scan done with the SA44B connected to an outside VHF-UHF discone antenna. It reveals the capture of an ADSB squitter at 1.090GHz from a passing commercial airliner. (See 'ADSB and Flightradar 24', SILICON CHIP August 2013).

Summarising

The USB-SA44B delivers a level of performance that is well and truly comparable with self-contained analysers costing many times its price.

Not only that, it also offers many of the features of an SDR-based measuring receiver.

In effect, the hardware of the SA44B and its matching software seem to have been so well integrated in a functional sense that they really can turn your PC into a high performance spectrum analyser.

So if you'd like to have the features and performance of a 4.4GHz spectrum analyser/measuring receiver but can't justify an outlay of $6800 plus, the Signal Hound USB-SA44B is well worth considering, especially at the price (as we mentioned earlier, a shade over $1300 including GST). SC

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Hole size: 45mm

$7.50

#40946

15A Quality Insulated Alligator Pack

Pack Inc. 2 x Black & 2 x Red
Slim crocodile clip made of brass
Jaw opening: 15mm
Overall length: 55mm,4mm Socket Entry
Volts: 300
Manufacturer: Testoon
* 4 Clips in total *

$5.50

#42454

30A Modular DC Connector Pack

You Receive 3 x Red & 3 x Black (Inc. Terminals)
*High current DC connectors as used in automotive and industrial applications. Can be dovetailed together for multi-pole connectors. 30A rated.
* 6 Connectors in total *

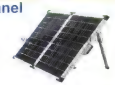
$5.80

#42455

12V 120W Folding Solar Panel

* In-built Controller for direct charging to battery

Rated voltage:12V
V at pmax:18.0V
I at pmax:6.98A
Open Circuit Vlts:21.6V
Lead Length:4.5m
Short Circuit Curr: 7.72A
Weight: 13kg



$229.00

#42333

96mm Wide Black Waterproof Gaffer Tape

* Gaffer / Duct / Cloth

Backing Material: PE(Polyethylene) Cloth
Width: 96mm
Length: 50m
Colour: Black
Adhesion Strength: 65N/mm²
Thickness: 0.165mm

$15.00

#42357

19mm 36kV EPR Self-Amalgamating tape

* Length 10M
* EPR Self-amalgamating tape
* Colour black
* Material Rubber
* Material Thickness 0.75mm
* Dielectric Strength 36kV/mm

Manufacturer: Scapa

$9.00

#42336

Soldering Iron Tip Cleaner and Holder

Soldering tip cleaner made of low abrasive brass shavings.

* No water necessary
* No temperature drop as in conventional sponges
* Cleans better than conventional sponges
* Anti-slip pad

Manufacturer: Pro`sKit

$6.90

#42351

6 Piece Mini Wire Brush Set

* Overall Length: 175mm
* Width: 15mm
* Handle Material: Plastic
* Bristle Material: Brassed Steel Wire
* Contents:Two Each of 175mm Brass, Steel, Nylon Brushes

Manufacturer:Duratool

$3.50

#42350

4 Button IP66 Hand Held Enclosure(Pk-2)

Device: CA-10,4

* Ergonomic design
* 20mm coin cell battery or 2 x AAA batteries Option
* Assembles with three screws
* Button membrane seals the enclosure making it meet IP 66

Colour: Grey

$6.50

#42408

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* Designed for fine assemble and adjustment operations on electronic circuits
* Made from high carbon steel
* Accurately machined
* Conductive handle

Manufacturer: PRO'SKIT

$6.50

#40418

Empty Cable Storage Drum **#42359**

An empty cable drum for storage and carriage of loose connecting power leads and audio/video cables. Stores up to
50m of 1.5mm² cable
Colour:Yellow
Manufacturer:ProPower

$20.00

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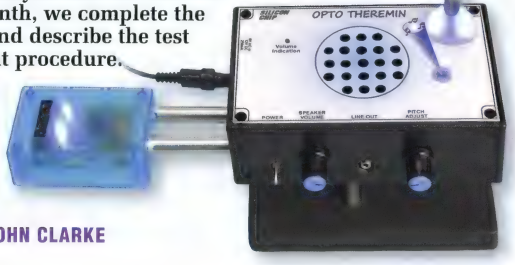
Completing, testing & adjusting the . . .

Opto-Theremin

In Pt.1 last month, we described how the Opto-Theremin works and gave the assembly details for the two PCBs. This month, we complete the construction and describe the test and adjustment procedure.



Pt.2: By JOHN CLARKE

THE OPTO-THEREMIN'S main PCB is housed in a black UB1 plastic utility box measuring 158 x 95 x 53mm. This box is supported on a timber plinth (or base) using threaded rods and three 50mm lengths of 10mm ID aluminium tubing.

The first step is to prepare the box by drilling the various holes. We've prepared a template (in PDF format) to make this job easy. This can be downloaded (no charge) from the SILICON CHIP website and printed onto plain paper – browse to www.siliconchip.com.au and then click 'Shop', 'by Year/Month' and select the month.

While you are there, download the front panel artwork and the drilling templates for the timber plinth and the smaller UB5 case. These can again be printed onto plain paper but for a better result, print the panel artwork onto photographic paper.

Next, cut the case template sheet into its various sections, then attach the templates to the case (eg, using adhesive tape) and drill the holes to the dimensions indicated. Use a small pilot drill to start the larger holes, then carefully enlarge them to their correct sizes using larger drills and a tapered reamer.

Be careful not to over-enlarge the 10mm-diameter the hole for the antenna. The aluminium antenna tube should be a tight fit into this hole.

Once the holes have all been drilled, the main label can be affixed to the lid using silicone sealant or a suitable adhesive. Allow the adhesive to dry, then cut out the various holes using a sharp craft knife. The speaker can then be secured to the inside of the lid by smearing a suitable adhesive (eg, super glue) around its outside metal frame.

Once the speaker is in place, it can be fitted with a short figure-8 connecting cable terminated in a 2-way header plug at the far end.

The main PCB is fitted into the box by first tilting it down at the front, so that the pot shafts and the switch can be slid into their respective holes. The

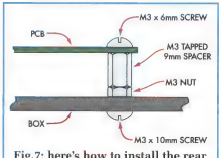


Fig.7: here's how to install the rear spacer assemblies. No spacers are required at the front of the case, since the PCB is supported along this edge by the two pot shafts.

rear of the PCB can then be pushed down into the case, after which the assembly should be secured in position by attaching the nuts to the pots. Do the nuts up firmly, then mark out the positions of the two rear mounting holes on the base of the case (eg, by hand-twisting a 3mm drill through the PCB holes).

That done, remove the PCB and drill these holes in the base out to 3mm. There's no need for corresponding front mounting holes, since the PCB is supported on this side by the pot shafts.

The rear spacer assemblies can now be installed as shown in Fig.7. First, an M3 x 6mm screw is inserted up through the bottom of the case. This is then secured with an M3 nut, after which an M3 x 9mm tapped spacer is fitted.

Don't reinstall the PCB yet – that step comes later, after attaching the case to the timber plinth.

Making the timber plinth

A piece of 151 x 90 x 19mm DAR (dressed all round) pine timber is used to make the base – see Fig.8. **Note that Fig.8 is not to scale, so you should download the full-size diagram from the SILICON CHIP website and print it out to use as a template.**

Cut the timber plinth to size, then round off the edges and the corners using sandpaper. The paper template can then be attached to the base and the three holes drilled to accept either M5 or 3/16-inch threaded steel rod (zinc-plated).

Countersink the holes on the underside to allow the nuts to be recessed. Fig.8 shows the cross-sectional view (two rods only shown).

The timber base is now used as a template to mark out the corresponding holes in the bottom of the case. Drill these to suit the threaded rod, then cut the threaded steel rod into three 75mm lengths. You will also need to cut three 50mm lengths of 10mm-diameter aluminium tubing, to serve as spacers.

It's a good idea to paint the timber base black to match the box colour. After that, it's just a matter of attaching it to the case using the 75mm threaded rods, 50mm aluminium tube spacers and nuts as shown in Fig.8.

Take care to ensure that the threaded rod protrudes no further into the box than the nut, otherwise it may later short against the tracks on the underside of the PCB.

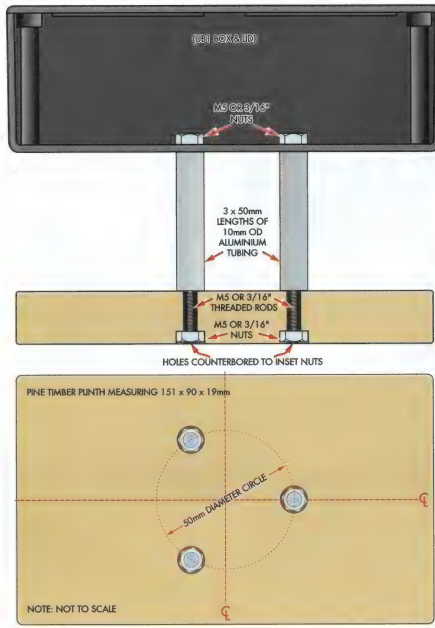


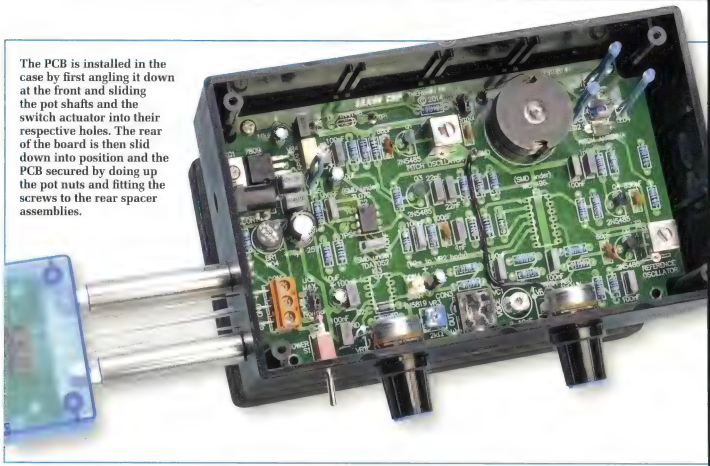
Fig.8: this diagram shows how the timber plinth is attached to the base of the case using three 50mm lengths of 10mm-diameter aluminium tubing and M5 or 3/16-inch threaded rods. Note that this diagram is not to scale. A full-size version can be downloaded from the SILICON CHIP website and used as a drilling template for the plinth.

The PCB can now be reinstalled in the case and secured to the previously installed rear spacers using M3 x 6mm machine screws. Tighten these screws down firmly, then install the pot nuts and fit the two knobs. If the knob pointers are in the wrong positions, prise the end caps off and refit them so that they are correct.

Volume control case

The volume control PCB is housed in transparent blue UB5 plastic utility box measuring 83 x 54 x 31mm. A rectangular cut-out has to be made in the base (which becomes the top) to accept the distance sensor, while five holes have to be drilled in one end for the external wiring connections and two threaded mounting rods.

As with the larger case, it's just a matter of attaching the drilling template downloaded earlier and then drilling the holes to the sizes indicated. The rectangular cut-out is made by drilling small holes around the inside perimeter, then knocking out the centre piece and filing to shape.



The PCB is installed in the case by first angling it down at the front and sliding the pot shafts and the switch actuator into their respective holes. The rear of the board is then slid down into position and the PCB secured by doing up the pot nuts and fitting the screws to the rear spacer assemblies.

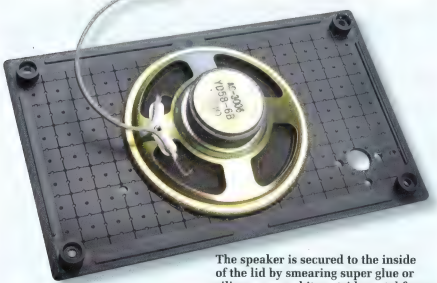
Be sure to make this cut-out in the base (not the lid). The case is later attached to the main case with the base facing upwards and the lid on the bottom.

Refer now to Fig.9 to see how the volume control case is attached to the main case. The first job is to cut two 62mm lengths of M5 or 3/16-inch threaded rod plus two lengths of 10mm OD aluminium tube. These aluminium tube pieces should be 50mm long minus the width of the nuts used (eg, if the nuts are 4mm wide, then cut two 46mm tube lengths).

Once you have all the pieces, attach the two threaded rods to the volume control case as shown in Fig.9; ie, for each rod, use a nut inside the case and another outside the case. We used Nylon lock nuts (metal nuts with a Nylon thread insert) because they each have a rounded end that the aluminium rod fits over and because they don't come undone.

The next step is to fit three straight 88mm lengths of 1mm-diameter steel wire to CON5 on the volume control PCB. These wires are then slid into the holes in the end of the case (between the nuts securing the threaded rods) and the PCB clipped into place (ie, into the integral ribs).

If you can't get steel wire, use 1mm-diameter tinned copper wire. This can be straightened by clamping one end in a vice and then stretching it slightly by pulling on the other end with a pair of pliers.



The speaker is secured to the inside of the lid by smearing super glue or silicone around its outside metal frame.

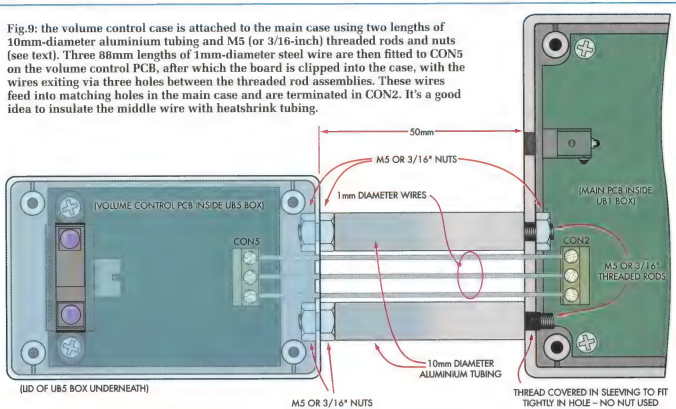
Final assembly

The volume control case assembly can now be attached to the main case as follows:

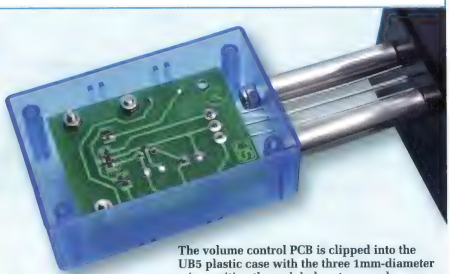
(1) Cover the front threaded rod (ie, at the bottom in Fig.9) with a length of 6mm-diameter heatshrink tubing. This heatshrink layer should cover the entire length of the thread and can be trimmed to size after shrinking it down.

(2) Cut another length of heatshrink tubing about 3mm shorter than the aluminium tubing and add this to the rod. Push it all the way up against the nut at the volume control case end

Fig.9: the volume control case is attached to the main case using two lengths of 10mm-diameter aluminium tubing and M5 (or 3/16-inch) threaded rods and nuts (see text). Three 88mm lengths of 1mm-diameter steel wire are then fitted to CON5 on the volume control PCB, after which the board is clipped into the case, with the wires exiting via three holes between the threaded rod assemblies. These wires feed into matching holes in the main case and are terminated in CON2. It's a good idea to insulate the middle wire with heatshrink tubing.



This close-up view shows how the end of one of the threaded rods is covered in heatshrink tubing so that it is a tight fit into its matching hole in the main case – see Fig.9.



The volume control PCB is clipped into the UB5 plastic case with the three 1mm-diameter wires exiting through holes at one end.

before shrinking it down.

(3) Repeat step 2, adding more heatshrink layers until the aluminium tube is a firm fit over this threaded rod.

(4) With the aluminium tubes in place, insert the three wires and the threaded rods into the main case, with the ends of the wires going into CON2. The heatshink-covered rod should be a tight fit into its hole.

(5) Secure the other threaded rod with a nut on the inside of the main case.

(6) Tighten CON2's screws to secure the three wires in place.

Making the pitch antenna

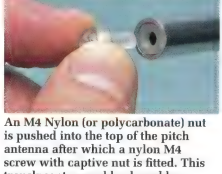
The pitch control antenna is also made from 10mm-diameter aluminium tubing. You also need an M4 x 10mm Nylon (or polycarbonate) screw and two M4 Nylon (or polycarbonate) nuts.

First, cut a 450mm length of the tubing and clean up the ends with a file to remove any metal burrs. That done, gently file each corner of one of the M4 nuts until it fits tightly into one end (ie, the top) of the antenna. Once it's in position, wind the second M4 nut all the way onto the screw and then screw this into the captive nut in the antenna.

This translucent 'top piece' provides the blue glow at the top of the antenna when lit by LED3 on the main PCB (ie, the blue LED that shines up the antenna tube).

The other three blue LEDs (LEDs1, 2 & 4) light the base of the antenna. As an option, these three LEDs can be covered with a translucent, half-hemispherical, hollow ball that's slid over the antenna and pushed down onto the lid of the main case.

A ball salvaged from an empty can of roll-on deodorant is suitable. All you have to do is cut the ball in half using a fine-blade hacksaw, file the ends to



An M4 Nylon (or polycarbonate) nut is pushed into the top of the pitch antenna after which a nylon M4 screw with captive nut is fitted. This translucent assembly glows blue when lit by the LED shining up the aluminium tube.

The pitch antenna is pushed into the two fuse clips on the main PCB assembly (usually after the lid is in place). LED3 is between the two fuse clips and shines up the antenna tube to light the translucent screw assembly at the top.

a smooth finish and drill a 10mm hole in the top. It's then simply slid over the antenna.

As previously stated, the bottom end of the antenna is connected into circuit by sliding it into the two fuse clips on the main PCB. It may be necessary to squeeze the lugs of these fuse clips together slightly so that the antenna makes a good contact. Rotating the antenna a few times will also clean the contacts if they oxidise over time.

For the time being, leave the lid off the case and simply support the antenna in its fuse clips. You are now ready for the setting-up procedure.

Setting up

The adjustment procedure is as follows:

Step 1: fit link LK1 (near the equalising coil) to the TEST position and LK2 to the MAX position.

Step 2: connect a 9VAC plugpack or a 12V DC source, switch on and check that all the LEDs light. If they don't light, check that they are orientated correctly.

Step 3: connect a DMM set to read DC volts between TPS (near IC2) and TP GND and adjust trimpot VR4 for a reading of 1.7V.

Step 4: connect the DMM between TP1 and TP GND and adjust the slug in transformer T1 for a minimum reading (note: do not use a screwdriver as this could crack the ferrite core. Either use the correct plastic alignment tool or grind down an old screwdriver so that its blade is thicker than normal and snugly fits the slot in the slug).

If you are unable to find the minimum, then either coil L1 has been incorrectly wound or its leads haven't been soldered. Check the solder joints and check also that the Nylon washer spacers have been installed to provide the required 2.5mm gap between the two core halves.

Step 5: move your hand very close to the antenna (but don't touch it) and adjust T1's slug so that the voltage slightly increases. When it does, move your hand away from the antenna and check that the voltage increases even further.

If the voltage decreases instead, then the slug needs to be rotated the other way. On the prototype Opto-Theremin, we adjusted T1's slug for 1.1V with the hand close to the antenna and 1.7V with the hand away from the antenna.

Step 6: move jumper LK1 to the NORMAL position, connect the loudspeaker to CON4, set VR1 to mid-position and set VR2 fully clockwise.

Step 7: adjust transformer T2 until a tone is heard and set it for a low frequency. This tone should then change if you move your hand away from T2 (and away from the antenna), so this may take some trial and error.

Step 8: rotate VR2 anticlockwise and check that the pitch can be adjusted to just reach a point where there is no sound. The frequency should then become audible again and increase as a hand is brought close to the antenna. If not, reset VR2 fully clockwise again and repeat Step 7, this time adjusting T2's slug in the opposite direction.

Note that these adjustments require patience and you may need to repeat the process several times before you get it right.

Step 9: adjust VR1 fully clockwise, then adjust trimpot VR3 to limit the volume so that it isn't high enough to cause spurious vibrations or noticeable distortion.

Voicing adjustment

Trimmer capacitor VC1 must now be adjusted to set the voicing. It's just a matter of tweaking it to obtain the required sound from the Theremin.

Note that there will be a point where, at the lowest frequencies, there's a 'snap-on' effect whereby either no frequency is produced or the tone suddenly snaps on and becomes audible with hand movement. This occurs because inter-coupling between the pitch and reference oscillators causes both oscillators to track together and if there's no frequency difference between them, there's no audible output from the mixer. However, as a hand is brought closer to the antenna, the pitch oscillator's tuning changes and it is eventually 'pulled' far enough to suddenly produce a different frequency to the reference oscillator.

Hand volume adjustment

The hand volume adjustments are all done on the main PCB as follows:

Step 1: move jumper LK2 back to the NORMAL position, then check that the volume control has a suitable hand-movement range. The volume should increase as the hand is moved away from the sensor and vice versa.

Step 2: if you want to change the range, connect a DMM between TPS and TP GND and adjust trimpot VR4 for a reading that differs from the 1.7V set earlier. Note, however, that if VR4 is set to give maximum volume too away from the sensor, the volume will rise again at close range (ie, as the hand is brought below 40mm). This is a quirky effect of the sensor itself and is cured simply by backing off the setting for VR4.

That completes the adjustments. You can now complete the unit by attaching the lid to the main case and reinstalling the antenna, with the translucent dome slid all the way down so that it covers the three LEDs. Take care when fitting the lid to ensure that the four LEDs go through their corresponding holes. You will find it easier to do this if you apply power so that the LEDs are lit.

Finally, fit the lid to the underside of the volume control box and your Opto-Theremin is ready for action. SC

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Rohde & Schwarz HMO1002 2-ch

While this is an 'entry-level' scope offering from Rohde & Schwarz, it is clearly designed by people who use their own products. This is reflected in the many simple but helpful features that they have built in, which all add up to make a product that is pleasing to use.

The first thing you notice after unpacking this scope is how small and light it is. It's narrower than a typical entry-level scope and very easy to carry via the handle moulded into the top of the case.

The screen isn't tiny though; while only 640 x 480 pixels it's quite tall and clear, with the controls packed quite tightly to make the space on such a small instrument.

It made a good impression when we first powered it on as it was ready to go within a couple of seconds. Some scopes make you wait quite some time before you can make the first measurement but not this one. Also, it's unusually quiet because it doesn't have (or need) an internal cooling fan. While that might seem like a minor point, a fan droning away can get on your nerves after a few hours of probing and testing.

While it is a basic scope, with two channels and 50MHz of bandwidth, it comes with a lot of standard features. That includes a graduated display, 1Mpoints memory, excellent vertical sensitivity of down to 1mV/division with low noise, a built-in 50kHz signal generator, a 50MHz pattern generator (more on that later), two-channel three-digit digital voltmeter and the ability to add eight logic channels and hardware serial decoding/triggering.

The bandwidth can be upgraded to

nnel Mixed Signal Oscilloscope

Review by NICHOLAS VINEN

70MHz or 100MHz at any time, via a software key. There are also software upgrades for the serial bus decoding and triggering.

It is supplied with two switchable 1:1/10:1 100MHz probes. Switchable probes are quite handy since they let you get good bandwidth when you need it (using 10:1) and high sensitivity when that's more important, without having to swap the probes.

User interface

The user inerface on this scope is above average and clearly designed by someone who has a lot of experience using a DSO/MSO (Digital/Mixed Signal Oscilloscope). This includes some features and capabilities that we haven't seen before, plus some clever button layout and menu functions.

For example, the Fast Fourier Transform (spectrum analysis) function has a dedicated front-panel button to toggle it on and off, rather than being hidden in a "Math" menu.

It's one of the better scope-based FFTs we've seen, automatically setting up the span, bandwidth and so on to minimise the amount of fiddling required to get a useful display. It can also be enabled with the scope in 'stop' mode, based on data already captured, which is quite handy. The FFT update rate is also quite fast.

Another example is the "Quick View" mode. At the press of a single front-panel button, this displays the currently selected channel trace (only) along with various useful annotations shown directly on the waveform; see Fig.1. Here you can see the positive and negative peak voltages, average (mean), rise and fall times along with cursors showing how these are calculated.

In Fig.1 you can see another feature that we like, which is that this unit can display up to six measurements at a time, in the bottom-right corner of the screen. Many scopes will only show four measurements simultaneously. While that's enough most of the time, when examining multiple signals, you can definitely run out and it's frustrating to spend a lot of time fiddling with the measurements menu to get around this.

As well as the usual measurements (frequency, peak-to-peak voltage, RMS voltage, etc) there are some interesting ones we don't see very often on a DSO. These includes crest factor, edge/pulse count, trigger period and trigger frequency.

These latter measurements allow you to recognise how often the trigger conditions are being met and therefore how many waveform acquisitions have been used to generate the trace display.

The HM1002 has the usual waveform acquisition modes – sampling, envelope (min/max), averaging and the always useful 'high-resolution' mode, which they label 'smooth'. It also has a bandwidth limiting mode as is usual; you can switch in a 20MHz low-pass filter on each channel to remove spurious noise. But it also has an adjustable low-pass filter mode which

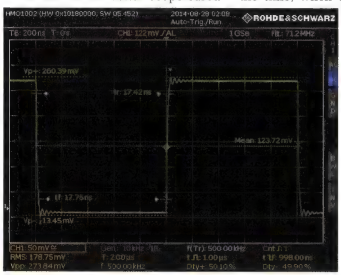


Fig.1: "Quick View" mode is available at the press of a button and shows several critical parameters superimposed upon the waveform from a single channel. Up to six measurements are also shown (lower right corner).

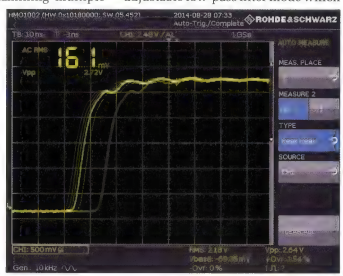


Fig.2: the fast waveform update rate (up to 10k/sec) and graduated display means that you can see variations in repetitive signals in quite a bit of detail. This shows what a square wave leading edge with jitter looks like.

gives much more freedom in filtering the signal and that's less common.

The minimum filter frequency you can select depends on the timebase. For example, at 1µs/div you can set the -3dB point down to 5MHz while at 500ns/div it will go down to 10MHz. This is a very handy feature when looking at noisy signals. In those situations, you have four main options: examine the unfiltered signal (limit by the scope's analog bandwidth), use the 20MHz filter, use the high-resolution filter or use this adjustable filter. Each has its own advantages.

Performance

The acquisition rate is 1Gsample/sec for one channel or 500Msample/sec for two, quite sufficient for a 50-100MHz scope. Acquisition rate is quoted at up to 10k waveforms per second which is well above average and in combination with the graduated display, quite useful for looking at periodic waveforms which are not fully consistent (see Fig.2).

Now, it used to be that basic DSOs came with a very small storage space of something like 8 or 16kpoints but that has now changed and the HMO1002 comes with 1Mpoints as standard (512k points per channel when using both channels). That isn't the biggest we've seen but it's certainly a decent size. If you get the optional logic probe head then there are 512kpoints storage per channel for logic data too.

The HM1002 claims to have low noise on its analog inputs and we have to say we are impressed. Fig.3 shows the display with both channels set to 1mV/div sensitivity, with channel 1 connected to the compensation signal and channel 2 grounded. As you can see, the traces don't have much fuzz and signal details well below 1mV in amplitude are visible. This is shown without any bandwidth limiting; filtering will make the traces even cleaner.

Pattern generator

This is quite an intriguing feature. When developing circuits, we sometimes need to send serial packets to various ICs to check that they are working. For example, if the output of a DAC chip is erratic, is it the signal source that's introducing errors or the DAC itself? This sort of problem can be frustrating to solve.

With this arbitrary 4-channel pattern generator, you can program the scope to produce SPI, I^2C, I^2S, biphase (S/PDIF) signals and so on, and inject these into your test circuit. You can then use the scope's normal functions to see how the circuit behaves. These signals are available at hook lugs on the front panel, to which wires can be clipped.

Fig.4 shows an SPI-like pattern that we set up in about a minute. You can do this on the scope itself; it's a bit fiddly given the limited input controls but it isn't too difficult. For more complex patterns such as message sequences, you can load the data onto a USB drive using a PC and thence into the scope. The pattern generator runs at an adjustable frequency up to 50MHz.

This would be great for determining whether serial transmission speed is an issue in your circuit, by having the scope transmit the same message constantly and then ramping up the transmission speed until it becomes garbled or unreliable.

Signal generator & DVM

These days scopes are increasingly coming with these sort of functions built in as they're handy to have on the test bench, without the clutter introduced with multiple test instruments. The signal generator in the HM1002 is rather basic but will serve a variety of purposes. It will generate sine waves up to 50kHz, square and triangle waves up to 10kHz and so on with adjustable frequency, amplitude, etc. Output is via a front panel BNC connector.

The Digital Volt Meter provides some functions not available with the usual measurement modes as the values displayed are based on long-term averaging rather than just whichever portion of the waveform happens to be on the screen at a given time. Having said that, as with voltage measurements, you need to set up the vertical scale correctly for the DVM reading to make sense.

The DVM features in this scope are better than many others we've tried. For a start, you can display two readings per channel at a time. So for example you could display RMS voltage and crest factor simultaneously. Another nice benefit of the DVM feature is that you can consider these readings as up to four extra measurements that can be

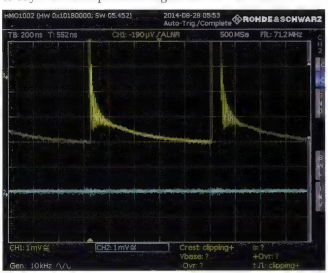


Fig.3: the 1mV/div setting is very usable and this shows off the low noise performance of the unit. For example, this could be handy when examining low-level audio signals. Many scopes will only go down to 5mV/div.

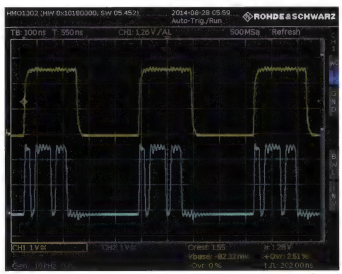
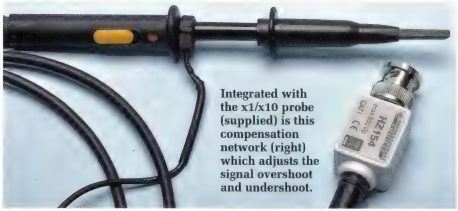


Fig.4: the built-in pattern generator can be used to produce digital or serial signals to inject into the device under test while you measure other parts of the circuit. The scope also comes standard with a 50kHz analog signal generator.



Integrated with the x1/x10 probe (supplied) is this compensation network (right) which adjusts the signal overshoot and undershoot.

displayed, meaning you can see up to ten measurements at a time, while still leaving a decent amount of space for traces. That's pretty good!

The DVM readings appear in one corner of the screen; you can choose which. In fact, many of the displays in this scope can be turned on and off or moved so that you can customise the screen layout. For example, you can turn the trigger and trace baseline cursors on and off, the graticule on and off, etc. You can fill the screen with measurements or de-clutter it entirely; whichever you prefer.

Some scopes (frustratingly) don't let you turn off displays that you don't need and which can get in the way. This one thankfully gives you control.

Responsiveness & features

For a small, entry-level scope, the user interface is definitely responsive. There are no obvious delays in responding to button presses and the screen refresh time is good. Too much hardware these days is laggy (we blame lazy programmers) and this can lead to much user frustration. Luckily, the HM1002 doesn't fall into this trap.

There are a lot more features than we have covered already. We don't have space to list them all. Pretty much everything you'd expect to find on a modern DSO is there. That includes various trigger modes, mask testing, XY mode, reference traces, zoom, roll, cursors, frequency counter, waveform maths and so on.

It even has a 'component tester' mode which injects some current into a device under test (eg, a diode) and does a quick current/voltage plot to let you check whether the component is working properly. We aren't sure just how useful this is in practical situations but it certainly doesn't hurt to have it available.

Build quality

The construction of the HM1002 is a bit lightweight. As stated earlier, that has some benefits and it's certainly convenient to pick up and move around. However the membrane buttons don't have the best possible feel. Also, many of the illuminated buttons are so bright that they bleed into adjacent buttons.

We've come across criticisms of the scope's 200V maximum peak input rating whereas other scopes may have a 400V rating and therefore are able to withstand direct connection to mains. But if you're going to be probing voltages that high, you should be using a 10:1 or even 100:1 high-voltage probe anyway. We'll gladly except a 200V peak voltage rating in exchange for the excellent low noise and high sensitivity of this unit.

Conclusion & availability

The HM1002 is an easy and convenient scope to use. It's the lightest and most compact 'proper' MSO that we've used and while its specifications are relatively modest, it has a lot of nice conveniences which make its usability a cut above average.

Recommended retail price of the HM1002 is $995.00 plus GST. A special introductory offer for SILICON CHIP readers will also include the normally optional SPI/I²C/UART/RS232 trigger and decode function. The logic probe will also be half-price.

For enquiries or to purchase a unit, contact Rohde & Schwarz Australia at (02) 8874 5100, e-mail them at sales.australia@rohde-schwarz.com or visit the product page at their website: www.rohde-schwarz.com.au/en/products/test_and_measurement/Oscilloscopes/HMO1002.html.

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Vintage Radio

By Malcolm Fowler

The Mullard 5-10 Ten Watt Valve Amplifier

One of the finest amplifiers available for hobbyists to build in the early 1960s was the Mullard 5-10 ultralinear valve unit. This had state-of-the-art performance and a working example would give a very good account of itself in comparison to the best valve amplifiers now available.

IN THE EARLY 1960s, I was fortunate enough to attend a school in the UK where the physics master was not only a great teacher but a hifi buff, electronics whizz and semi-professional sound recordist. These extra-curricular interests were put to good use in the running of a radio club and the production and recording of school plays and concerts. Students involved in the radio club, of which I was a member, were recruited to build and operate an array of audio equipment.

We had at our disposal several Ferrograph tape recorders, a record-cutting lathe and a multitude of Mullard-designed mixers, preamps and power amplifiers. The majority of the Mullard-designed equipment, based on "Mullard Circuits for Audio Amplifiers" published in 1959, was built by the students and this was my introduction to a lifelong interest in audio and electronics.

Fifty years later and a wave of nostalgia had me thinking of revisiting these valve amplifiers, not because I prefer valve sound but just for the delight of it and particularly the glow of the valves. Solid-state may give great sound but it lacks a certain charisma!

I initially looked into building a pair of 10-watt Mullard 5-10s from scratch but the availability and cost of components, particularly transformers, seemed to rule this option out. Consequently, I started looking at vintage amplifiers suitable for restoration such as the Leak Stereo 20 but again cost was an issue. Leak Stereo 20s typically sell for well in excess of $1000 and then need to be refurbished.

Aegis 5-10 amplifiers

After some research, I eventually came across two dissimilar Aegis 5-10 amplifiers being offered for sale on the internet. On the spur of the moment, I bought them, sight unseen, for far less than the cost of a new mains transformer. I knew relatively little about these amplifiers other than that they were built by the Aegis Manufacturing Company in Melbourne in the late 1950s and early 1960s and that they adopted the Mullard 5-10 amplifier designs in their various formats.

These amplifiers could be purchased new as individual units for £40/5/- (forty pounds five shillings) in 1959. They were also incorporated by other manufacturers into high-end console units.

My secondhand amplifiers, complete with all their valves, survived the journey from Queensland to Melbourne via Australia Post. As mentioned, the two units were dissimilar, both physically and electronically. The first (Serial No: 378), which I shall refer to as 'Amp1', was built on a single-level steel chassis and was fitted with A&R mains and output transformers. The circuit was exactly to the Mullard 5-10 design for "Distributed Loading" (also called ultralinear), where the screen grids of the output valves are fed from tappings on the output transformer.

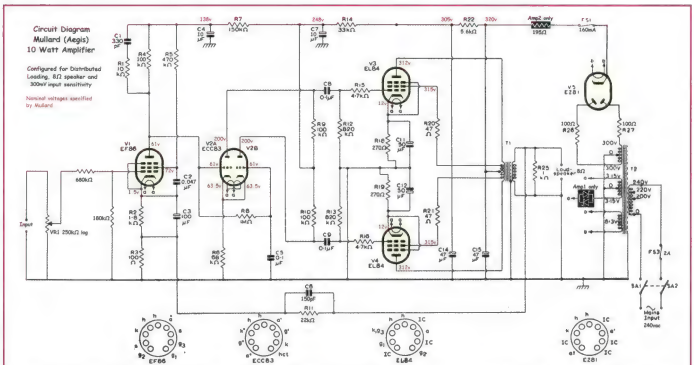


Fig.1: the circuit of the Mullard (Aegis) 10W amplifier. V1 (EF86) is a voltage gain stage and this drives an ECC83 twin triode (V2) operating as a phase splitter. V2 in turn drives two EL84 pentodes (V3 & V4) operating in ultralinear push-pull mode. Feedback is applied from the output of the speaker transformer back to the cathode of the EF86 pentode.

This configuration is used to achieve a compromise between the performance of the two EL84s when connected as triodes and pentodes. Sufficient power reserve is maintained yet distortion is much lower than with a normal pentode connection.

The second unit (Serial No: A272), which I shall refer to as 'Amp2', was built on a stepped aluminium chassis and was fitted with a National mains transformer and a Barco output transformer. The circuit was exactly to the Mullard 5-10 design for "Low Loading" where increasing the cathode resistance and lowering the anode-to-anode load to 6kΩ results in a reduction in quiescent current from 36mA to 24mA.

This configuration is recommended for use with speech and music as it has low distortion and lower power consumption. However, it cannot cope with continuous sinewave inputs.

Both units came with passive tone control modules built to the Mullard specification. I had no interest in using these as from my experience they only detract from the performance of the main amplifier due to reduced sensitivity and hum and noise pick up.

Checking the components revealed that the main filter capacitors were beyond redemption and most of the resistors were reading at least 20% high.

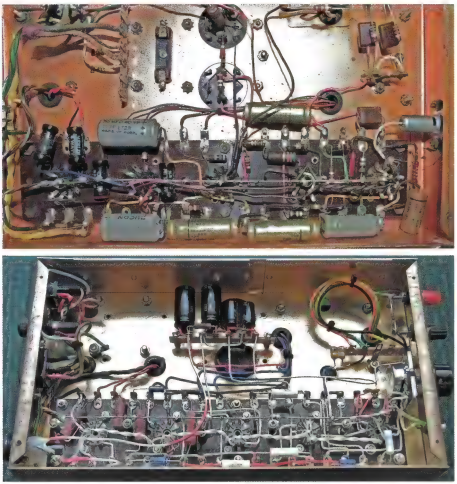
This view shows the two Aegis valve audio amplifiers and their associated tone control units as purchased by the author. Both amplifiers required complete rebuilds before they could be used (the tone control units were not restored).

The valves were tested by a friend and were found to be serviceable but of varying quality. The two power transformers tested as good, passing both voltage and insulation tests with flying colours. The one disappointment was that the A&R output transformer on Amp1 had an open-circuit primary somewhere deep within the winding!

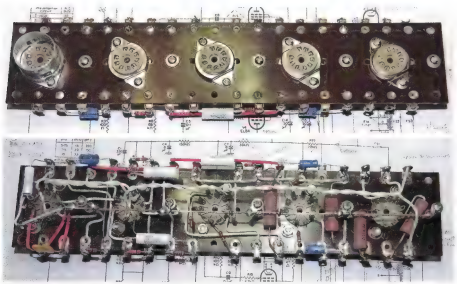
Due to the state of the filter capacitors and the open-circuit output transformer on Amp1, no attempt was made to power up either of these amplifiers in their original state.

Decision time

The difference in output formats, the failed output transformer and the state of the components, wiring and connectors made it clear that complete rebuilds would be necessary to create two functional matched amplifiers for stereo use. I wanted to rebuild the amplifiers in the 'Distributed Load'



These two under-chassis views show one of the Aegis amplifiers (Amp1) before restoration (top) and after restoration (above). Note the turret board with the valve sockets and other parts at the bottom.



This is the rebuilt turret board for Amp1. It was fitted with new valve sockets and new capacitors, resistors and wiring. Note the spacers between the sockets and the associated earth bus bar.

output format as this, in my opinion, is the best of the Mullard alternatives. To do this, I would need a new matched pair of output transformers which wasn't going to be cheap. However, I already had a purchaser in the wings for the Barco 'Low Loading' output transformer in Amp2 so this would offset the cost to some extent.

I would also need to purchase a full complement of capacitors, resistors and other hardware to complete the renovation. I assumed at this stage that the valves would be acceptable, at least initially. I was hooked – it was certain that I was going to proceed!

Purchasing the parts

The biggest purchase decision involved the output transformers. After some considerable research, I decided to order a pair of Transcendar output transformers from the USA. These have an 8kΩ primary impedance, screen grid taps at 40% and a power rating of 30W. The transformers are built to order and are very competitive with locally equivalent products, even with freight costs included.

The capacitors and resistors were ordered from Digi-Key in one lot so as to minimise the impact of shipping. The reason I ordered from Digi-Key is that I had a wide choice of well-known brands, full specifications and in most cases the prices were very competitive. Add to that a shipping time of around six days and it stacked up well.

I selected Panasonic EE series electrolytics for the filter capacitors, Vishay BC for the low-voltage electrolytics, Cornell Dubilier for polyester film and mica capacitors, Vishay Dale for the wirewound resistors and Vishay BC for all other resistors which were 1W 5% metal film types. The required axial format and working voltages limited the choice of capacitors in certain instances.

New Belton Micalex valve sockets (fitted with skirts for the EF86) were also ordered, while the wiring ordered was stranded 22AWG hookup wire from Alpha Wire. This wire, trademarked as 'EcoWire', is insulated with a wall thickness of only 0.23mm PPE (polyphenylene ether) and has a 600V DC rating. It's not cheap but it is great to work with as the insulation, similar to PTFE, is not affected by the heat of soldering and the overall diameter makes it easy to fit into relatively tight spots.

Other hardware such as potentiometers, fuseholders, speaker terminals, RCA sockets, switches and mains IEC connectors came from my existing stocks on hand.

Dismantling & preparation

Both amplifiers were completely dismantled back to bare chassis and

Use Safety Fuses

Note that the fuseholders shown fitted to these units are not recommended for mains or other high-voltage (HT) work. These days, mains safety fuses (eg, Jaycar SZ-2025 or Altronics S5977) should be used to eliminate the possibility of electric shock when removing the fuse.

all unnecessary connectors removed. New holes were then cut as necessary to provide for the speaker terminals, volume control, RCA input socket, IEC mains input, mains switch and two fuseholders (mains and HT). The remaining holes from previous fittings were blanked off with steel or aluminium plate, depending on the particular chassis.

The aluminium chassis was much easier to work with but the rigidity of the steel chassis made it the preferred option. After a thorough degrease, all metalwork was spray-painted, first with primer and then "Old Gold" hammertone finish enamel. The two chassis were then put aside to allow the paint to thoroughly harden.

The turret boards with valve sockets incorporated were stripped down, desoldered and all terminals cleaned with a Dremel wire brush. The original valve sockets were removed by drilling out the mounting rivets and the boards given a final clean with isopropyl alcohol.

It was my original intention to 're-stuff' the old filter capacitors with new, physically much smaller, 450V DC capacitors. However, the cases disintegrated during the removal of the bases so that idea was shelved in favour of new sub-chassis tag boards.

Rebuild

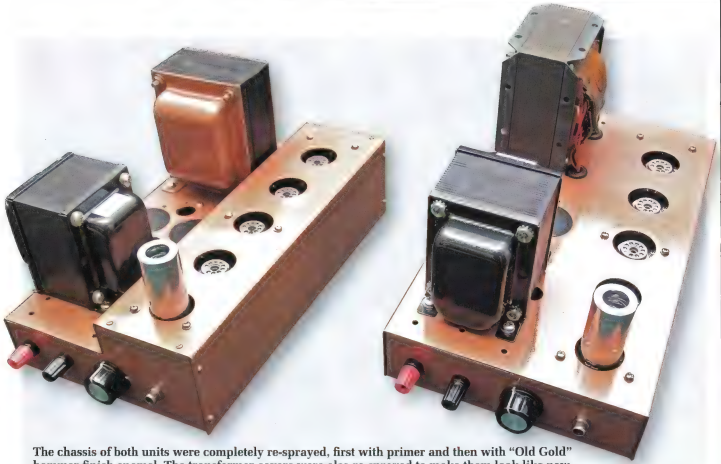
Once the components arrived, I reassembled the turret boards. The new valve sockets were secured using M3 machine screws and nuts. The new valve sockets didn't have central spigots on which to mount a ground bus bar, so I fitted spacers to the tagstrip between each valve socket. A solder tag was then fitted to the top of each spacer to create a mounting point for the bus bar. All ground connections were made to this bus bar which itself was earthed only at the input socket.

All the links were then installed followed by the components, care being taken to insulate long leads where relevant. Once the turret board was fully assembled, it was checked, checked again and then checked again – first against diagrams I had made of the original installation, then against the Mullard schematic and finally against photographs I had taken of the original board.

The new connectors, volume control, power socket and fuses were then fitted to the chassis. The transformers were then re-attached, albeit in a different orientation. It was necessary to change the orientation so that the coils of the mains transformers and the new output transformers would be at 90° to each other to minimise hum pick up.

I checked these locations by first powering up each main transformer and then connecting my oscilloscope to an output transformer secondary. The scope was then monitored while I changed the orientation of the output transformer. My conclusion was that

These photographs show the two fully-restored amplifiers with their transformer covers removed. Note that the fuseholders shown here are not the recommended types for mains and high-voltage work (see panel).



The chassis of both units were completely re-sprayed, first with primer and then with "Old Gold" hammer-finish enamel. The transformer covers were also re-sprayed to make them look like new.

orientating the output transformer at 90° relative to the mains transformer made a big difference! On Amp2, it was necessary to modify the transformer cover slightly to accommodate the output transformer, as it was not possible to re-orientate the mains transformer.

The turret boards were then reinstalled and the necessary connections to the transformers, sockets and fuses etc completed. The filter capacitors and their associated dropper resistors were assembled on a tagstrip close to the original location for these parts. Although a fiddly process, it was very satisfying to see the end approaching.

The moment of truth

Once everything was complete, I repeated the checking procedure – I didn't want expensive smoke coming out of those new output transformers!

It was then time to fire up the first amplifier. I set Amp1 up with a full complement of valves and connected an 8Ω dummy load to its output. I then connected my multimeter to the HT line and slowly ramped up the voltage from the Variac.

First, the neon indicator in the mains switch came on, then the valves started to glow and the HT voltage began to increase. I increased the Variac voltage to 180VAC and let it stay at that for some time. It all seemed good; there was no smoke and the voltages looked about right. I then increased the voltage to 240VAC and it all still seemed to be OK.

The next step was to connect a speaker and a signal source and much to my satisfaction, undistorted sound was the result. In short, it all seemed to be performing correctly although there was a little more background noise than I would have liked – not hum, just "white" noise. I then put Amp2 through the same process with the same result.

Once this initial trial was over, I decided to check all voltages against the Mullard specifications and run a frequency response curve using TrueRTA software. It's worth noting that at this stage, both units still had their original valves.

The voltages were largely in line with Mullard's figures. However, the heater voltage in Amp1 and the HT in Amp2 were a little too high for my peace of mind. Another issue of note was that the anode voltage on the EF86 and the corresponding grid voltage on the ECC83 were about 20% low, although the sound was fine and I was assured that this was acceptable by those 'that know'. It was also thought that this may be due to "tired" EF86 valves.

The frequency response at 1W using TrueRTA was within -2dB from 20Hz to 20kHz. The noise floor was

Links For Additional Information

Mullard Circuits for Audio Amplifiers – First published April 1959 (51MB PDF download): **www.basaudio.net/blog/wp-content/uploads/2013/01/19400164-Mullard-Circuits-for-Audio-Amplifiers.pdf**

Mullard 5-10 Amplifier: **www.r-type.org/articles/art-003e.htm**

Aegis Basic 10W Ultra-linear Amplifier: **www.radiomuseum.org/r/aegis_ultra_linear_basic_amp_510.html**

Transcendar Transformers: **www.transcendar.com/3.html**

The completed valve amplifiers (one for each channel) are used in a stereo set-up with a pair of Celestion Ditton 15 loudspeakers. A CD player (not shown) is used as the signal source.

obviously higher than specification at somewhere around the -54dB mark (the specification is at least -75dB at 10W).

Tweaking & listening

The HT voltage in Amp2 was reduced to below 320V DC by installing a 195Ω resistor prior to the first filter capacitor. A pair of back-to-back Schottky diodes were also installed in the heater supply of Amp1, thereby reducing the heater voltage by 0.4VAC to just below 6.3VAC overall.

It was always my intention to use these two amplifiers in a stereo configuration, initially using a CD player as a signal source and Celestion Ditton 15 loudspeakers which I had purchased new in 1970. The input sensitivity of each amplifier is 40mV for full output and this needed to be attenuated to suit the CD player's output and to allow an 'upstream' remote motorised stereo volume control to be included.

The suggested Mullard attenuation for use with their 2-valve and 3-valve preamplifiers proved to be just right. This modification was made 'downstream' of the inbuilt volume control which is really there for the purpose of setting the balance between the two amplifiers.

Subsequent listening tests proved to be very satisfactory. The increased background noise was annoying but easily forgotten; I particularly liked the sound of classical piano, violin and solo vocals.

New valves

As the weeks went by, I really felt that I had to install a new set of valves of known quality to see what improvement could be achieved. I disappeared into the world of 'New Old Stock' (NOS) valves, new manufacturers, Mullard valves that aren't Mullard at all, JJs versus EH etc. It's a whole new world out there and most of the emphasis is aimed at guitar amplifiers where they want controlled breakdown and distortion and 'musicality'!

Fortunately, there is another sector that is more focused on audio and this tends to be where NOS is hallowed and overpriced. A genuine 1956 Amperex Bugleboy ECC83 from the Mullard Blackburn factory could compete with Penfolds Grange in price and desirability!

To cut a long story short, I managed to obtain pair of NOS Tesla EZ81s from Bulgaria, a pair of Siemens EF86 pentodes from Serbia, and a pair of matched Raytheon ECC83 triodes and matched pairs of Raytheon EL84 pentodes from the USA. These valves were all produced in the 1960s, had never been used and tested as new.

Interestingly, the Raytheon valves were all originally produced in Japan by Hitachi and branded as 'Baldwin', for use in organs. I was told that only the best valves were reserved for the audio amplifiers in organs!

The new valves were installed and the lack of background noise was immediately apparent; both amplifiers now measured at better than -78dB. I listened for many hours to run the valves in and it was (and still is) a very pleasant experience.

After about 40 hours, I rechecked all the voltages. They were very close to specification and identical between Amp1 and Amp2. It still seemed to me that the anode voltage of the EF86 was too low so I decided to reduce the anode load resistor from 120kΩ to 100kΩ. That increased the voltage and slightly reduced the voltage gain. I can't say that I've noticed any difference in the sound but it makes me feel better to be within the middle of the specification rather than at one end!

I am satisfied that the amplifiers are now complete. The covers have been put in place and custom labels affixed. A remote stereo volume control is operational and I enjoy the listening experience and the glow from the valves. I make no claim that they sound better than my Luxman L410 which I love but they do make a very satisfying and alternative sound! **SC**

Acknowledgement: I would like to acknowledge my physics teacher Dr K. G. (Doc) Britton, Rydal School, UK 1941-1976.

ASK SILICON CHIP

Got a technical problem? Can't understand a piece of jargon or some technical principle? Drop us a line and we'll answer your question. Send your email to silicon@siliconchip.com.au

Doubts about bass response of the Majestic

Has anyone pointed out that the low-frequency response given in Fig.1 of the "Majestic" speaker article is impossible with the Etone driver, given its 3% efficiency and the size of the enclosure? In the August 1976 edition of "Audio" magazine, W.J.J. Hoge described a sub-woofer with a 20Hz -3dB cut-off frequency and 1% efficiency. The enclosure volume was 600 litres! You have published a design that has around one third the volume and three times the efficiency with an unspecified cut-off frequency somewhere below 20Hz.

Using equations from Richard Small's "Vented-Box Loudspeaker Systems Part 1: Small-Signal Analysis" (Journal of the Audio Engineering Society June 1973), for a completely lossless system, with the alignment of absolute maximum efficiency, to achieve 3% efficiency and a -3dB cut-off of 20Hz, an enclosure volume of 1000 litres is required. Using Mr Hoge's design as a guide to practical system efficiency, an enclosure upwards of 1800 litres is more likely. (I. M., via email).

● Allan Linton-Smith replies: the overall response of the system is not just a result of the enclosure design. It is also the result of the crossover network which was presented separately in the June 2014 issue. The crossover for the Majestic woofer has been deliberately designed for a 3dB point above 500Hz but the tweeter -3dB point is around 4kHz while it is also heavily attenuated.

In fact, as you can see from the frequency response curve in Fig.1 on page 24 of the June 2014 issue, the woofer response is not flat to 20Hz but drops off gradually from 100Hz and the response dips at 1kHz. The overall response is calculated as being from 20Hz to 20kHz within +6dB and -3dB, compared to the reference level at 1kHz.

You might say we have combined a low-frequency "hump" at 100Hz with a tightly controlled tweeter to give a commendably flat overall response.

In answer to your question of the "unspecified cut-off frequency somewhere below 20Hz", none of our Bruel & Kjaer microphones are calibrated below 20Hz so we could not justify any measurement below this frequency. We doubt any hifi speaker manufacturer would ever quote such a figure. Having said that, the Audio Precision impedance measurement in Fig.3 is an electrical measurement (not a SPL measurement) and indicates that there is a significant resonance at 10-12Hz. This undoubtedly demonstrates that there will be some sound (albeit inaudible) present at this wavelength.

Unfortunately, mathematical calculations based on simplified systems can often be wrong when you are dealing with multiple or innovative design features. We do not doubt your calculations show that it is "impossible" but there are a lot of unknowns. For example, the Thiele-Small parameters quoted by manufacturers can often be way out, especially Fs and Vas figures, and don't forget damping factor, cone compliance, stiffness and other unknown variables.

The overall result is mainly due to a combination of small improvements we incorporated through hard work and trial and error and we can theorise all day about the cabinet volume "seen" by the woofer but cannot always explain this mathematically. However, we do know that it works and our response curves are as accurate as our measurement system will allow.

Can Majestic be built with a bottom panel?

The adjectives describing the Majestic Loudspeaker System in the June

Performance Likely To Suffer If Cabinet Is Changed

I love speaker projects and it's great to see a really big one like the Majestic system featured in the June & September 2014 issues. However, I have a quick question. The woofer specifications don't list an Xmax (maximum cone excursion) that I can find. I was wondering how it would actually handle cone excursions at the higher power levels as it may be limited there rather than what the motor (voice coil etc) can handle power wise.

I was looking to make a much slimmer, taller and deeper box and would start with a simple one-port design since what was published is well beyond my capabilities with horns etc. However, not being able to model the excursion (I use WinISD alpha) is putting me off. (A. G., Brisbane, Qld).

● Allan Linton-Smith replies: Etone do not specify Xmax for that particular driver but I have driven it to a measured 300 watts RMS with music (hard rock) and it handled it with ease!

The actual construction of the Majestic is easier than it looks! The internal carcase (Bunnings 450 base cabinet) can be constructed in a couple of hours but if you change the dimensions you will not necessarily get the same result.

If 300 watts is not enough for you and you need power handling up to 1000 watts RMS at 97dB/watt @ 1 metre then you might like to consider spending a little more and use the Celestion 15-inch 28/FTR15-4080FD which fits exactly in the hole we recommended for the Etone 1525.

This has an Xmax of 6mm and we have also tested this speaker at high power levels successfully. You can purchase this driver from www.elfa.com.au

2014 issue were so impressive that I had to build and try them. While we wait for the replacement horn design, I would like to ask a question about the bottom of the speakers.

From the original article, in the base there is a port with a hyperbolic plywood structure which indicates that the speakers are designed to sit on the floor, supported by the cabinet sides and rear pieces. What if the speakers were to be mounted on a wall? Is it just a simple matter of adding a solid base panel? (C. W., Newcastle, NSW).

● Yes, you can build the Majestic with a bottom panel but that will increase the overall height of the enclosure.

Wants scaled-down version of Majestic

I read the article on the Majestic loudspeaker in the June 2014 issue with interest. They look great as are their stated specifications but I don't like the $1300 price tag. I understand they are significantly cheaper than other similar speakers on the market.

With that said, I wonder if it would be possible to produce a scaled-down pair of good-quality speakers that may end up being able to be made for around $600? I understand that the quality and specifications would probably be reduced proportionately.

The speakers would be 2-way and I imagine that the Majestic's crossover network would be used. The scaled-down speakers could, perhaps, be called "The Jestors" because they aren't quite majestic but are watered-down impersonators instead. A reduced price tag would also make them attractive to a larger segment of the population.

● It may be possible to do a scaled-down version of the Majestic but it really depends on the available woofers and their Thiele-Small parameters as these are primarily what determine the enclosure dimensions for the low-frequency response. We would not necessarily use the same crossover network. However, it is extremely unlikely that a smaller driver and cabinet would result in a frequency response down to 20Hz. That was one of the key performance factors we were striving for. In fact, we were hoping to get down to around 25Hz but we comfortably exceeded that.

Mind you, the main component of the Majestic cost is the cabinet with its high-quality finish. There is nothing to stop constructors from building their own cabinets and thereby saving a large amount of money.

Optimising damping in the Majestic

I have a minor question regarding the Majestic Loudspeaker System. I understand that sometimes bass reflex designs can include the series resistance of the inductor for optimising the damping. Is this the case with your design? (It's easy to add three parallel 3.9Ω resistors as replacement if required). (J. E., via email).

● We are not sure what you mean by "include the series resistance of the inductor". In fact, for optimum damping of the woofer, it is important that the resistance of the inductor is as low as possible.

Possibly, you are referring to the technique of "impedance equalisation" that's often employed in the network to the woofer. This takes the form of a series capacitor and a resistor (equal to the DC resistance of the woofer), which is then connected in parallel with the woofer.

The combination of this RC network and the woofer is a special case of a parallel tuned circuit which behaves like a resistor. It effectively cancels the inductance of the woofer itself and

Wideband Oxygen Sensor Controller

I made the Wideband Oxygen Sensor Controller from the September & October 2009 issues, tested it and made the setting as described on the magazine. The readings are all OK and it's generally working fine.

However, near the stoichiometric point, there is an oscillation which should not be there. The reading is smooth right until the stoichiometric point, then it jumps all over at this point and past that it's smooth again.

I see this behaviour on some other wideband controllers. Some have it, some don't. How can this be fixed in the Silicon Chip design? (M. K., via email).

● You can adjust the display response by increasing the value of the capacitor at the input to the wideband output buffer (IC2c). The original capacitor is 220nF at pin 10. You can increase this to, for example, 10µF (with the plus lead orientated so it connects to pin 10 of IC2c). This will slow the response time to around one second.

Changes around the stoichiometric point can be simply due to the way the vehicle's engine works at stoichiometric. When using the wideband controller, the wideband sensor replaces the original narrowband sensor and the narrowband output from the wideband controller is then used to simulate the narrowband sensor for the vehicle engine management computer (ECU).

The air/fuel ratio will oscillate at stoichiometric since that is just the way the vehicle's ECU works with a narrowband sensor (or signal from the wideband sensor). That is because the signal is essentially a switch in voltage for mixtures rich and lean from stoichiometric.

The engine is operated at slightly lean mixtures when the narrowband sensor signal output goes above 0.45V and slightly rich when the sensor output signal goes below 0.45V. This occurs over typically a one second period.

The oscillation occurs when the mixture control is in closed loop operation, where the ECU attempts to maintain the stoichiometric mixture about the threshold voltage (typically 0.45V) of the sensor between rich and lean. Outside closed loop (open loop), the mixture goes to rich or lean with values that are a function of predefined conditions stored in the ECU's memory and it does not rely on the oxygen sensor.

This rich/lean oscillation at stoichiometric is typical of all vehicles that originally used a narrowband oxygen sensor. New vehicles that are designed to use a wideband sensor do not oscillate the mixture at stoichiometric.

By the way, we published an improved Wideband Oxygen Sensor Controller in the June-August 2012 issues. You can see a 2-page preview of the June 2012 article at www.siliconchip.com.au/Issue/2012/June/Wideband+Oxygen+Sensor+Controller+Mk.2%2C+Pt.1

Water Cooler Causes EM Interference

Some time ago, I began using bottled water from a bench-top dispenser of the type that utilises a large plastic bottle on top. My family appreciates the ability of the dispenser to cool the water.

I believe the cooling system uses a Peltier Effect thermoelectric device. This cooling system may be switched on or off. When it is switched on, a small fan also operates. I believe its task is to remove the heat from the Peltier device.

My problem is that when the cooling unit is switched on it causes radio interference to the extent that the radio is unintelligible. This interference is transmitted back through the house wiring and is also radiated through the air. This is evidenced by the fact that two radios were used to check the situation. One was mains powered (about 10 metres from the source) and the other a battery operated unit about three metres from the source.

Any suggestions would be very welcome as I would like to solve the problem before the warmer months arrive. (G. H., via email).

● We suggest you try fitting one or two clip-on ferrite filters to the power cord (available from eBay and elsewhere). Failing that, try using a power board with an in-built filter. This strategy assumes that the interference is radiated by the mains wiring in your home. However, the unit itself may be radiating interference and that will require modification to the drive circuitry for the Peltier device or more effective shielding.

prevents it from reducing the required treble roll-off in the crossover.

We have not employed impedance equalisation in the Majestic because the 15-inch woofer naturally rolls off its high-frequency response quite rapidly above 2kHz.

What are MMC capacitors?

Excuse my ignorance but I am having difficulty locating some capacitors for a project of yours. What does MMC mean with regards to a capacitor. Your 2.GHz frequency counter project (SILICON CHIP, December 2012, January & February 2013) calls for 25 100nF through-hole MMC caps and five 10nF through-hole MMC caps.

I have tried different suppliers but it's very confusing as to the correct type. Are they metallised polyester? (E. B., via email).

● MMC stands for "Monolithic Multilayer Ceramic". This type of through-hole ceramic capacitor is normally encapsulated in plastic (usually blue or yellow), as opposed to the disc type.

Ceramic disc, metallised polyester or polyester film capacitors would also likely work for this project and in just about any other situation where multilayer ceramic capacitors are specified. The main reason we specify MMC capacitors is because they are the cheapest non-polarised capacitor for values between about 10nF and 1µF and are suitable in applications where linearity isn't critical, such as bypassing and AC-coupling.

The term MMC now seems to being supplanted by "MLCC" which stands for multi-layer ceramic capacitor.

Can DVD motors be run as steppers?

Does anyone at SILICON CHIP know how the disc drive motors in DVD burners are wired internally and can the Mini Stepper Motor Controller featured in the May 2002 issue be modified to drive them? (B. Z., via email).

● DVD motors cannot be used as steppers. We have a comprehensive article on converting such motors into high-power brushless motors in the July 2012 issue. You can see a 2-page preview of the article at www.siliconchip.com.au/Issue/2012/July/Modifying+CD-ROM+Motors+For+High+Power+Operation

Cleaning up a composite video sync signal

Have you ever published a composite video sync reinsertion project or kit?

We need to clean up the video signal coming out of an 1980s industrial control panel so that a modern monitor can be used. There is virtually no vertical sync; the monitor says "no signal". (H. R., Plymouth, NZ).

● Although intended to clean up Macrovision signals in the composite video on video tape, the Dr Video Mk2 from the June 2004 issue (or Dr Video from April 2001) should also clean up the sync signal.

Power tool soft starter is not working

I have had much pleasure in constructing the Soft Starter For Power Tools (SILICON CHIP, July 2012) and am confident that it complies with the design. Regrettably, when I connected it to my 9.5-inch circular saw, I detected no discernible difference in the tool's performance. It does not wind up, ie, start off slower than normal. The motor just kicks off at full speed as usual.

I appreciate how difficult it would be to diagnose a problem from a feeble complaint that a kit constructed by a hobbyist failed to perform but I am hoping you may be able to direct me to a likely or common cause for this. Or perhaps you can provide me with some clue to assist with the diagnosis (eg, check that both thermistors heat up).

I would dearly like to have this addition to my workshop and would appreciate any advice you might offer. (D. R., via email).

● It could be that the relay contacts are fused shut or that the circuit activates the relay immediately without the delay. A fused contact can be diagnosed by measuring the resistance across the contacts.

For the circuit, check that the 220nF capacitor is soldered in correctly (ie, no dry joints) and that all parts are correctly positioned on the PCB. Using the correct value resistors across the comparator inputs is important. If you use a socket for the LM339 check that all the pins are inserted in the socket and not bent in underneath.

You should check that the thermistors are about 10Ω each when cold. Check also that the Neutral in and out wiring is correct.

Doubts about battery life extension

I am sceptical about a battery sulphation prevention device being promoted at http://digitalpulsegenerator.com.au/ Is it likely to be effective?

At another website – http://battery

Dim Digits On The GPS Clock

About five years ago I built the 6-Digit GPS Clock (SILICON CHIP, May & June 2009). Early this year the large digits were each becoming quite dim and now cannot be read during daytime and are even too dim to be seen properly at night from the rear of my small house.

Have you come across this problem and if so what could be wrong? It is expensive to replace them but I can't think what else could cause the dimming. (R. B., Flaxton, Qld).

● We haven't come across this problem before and as far as we know most of the 6-Digit GPS Clocks are still running at full original brightness. This includes our original prototype which has been running continuously since about March 2009. It has the 'autodim' modification (SILICON CHIP, September 2009) but in daylight it still runs with the original brightness.

You don't actually mention whether you fitted the autodim circuit but it's possible that if you did so, your dimming problem might be due to the LDR light sensor on this add-on board having drifted quite significantly in value. This seems much more likely than any other component having become faulty or changed in value – or the 'large digit' LEDs having 'worn out' or otherwise dropped in efficiency.

So if you have fitted the autodim modification board, try replacing the LDR as your first step in tracking down the cause of your problem.

If that doesn't work, you might try replacing some or all of the LED segment driver transistors (Q8-Q14) and perhaps digit driver transistors Q15-Q18, as one or more of these may have become faulty.

MISS THIS ONE?

Published in Dec 2012

2.5GHz 12-Digit Frequency Counter

with add-on GPS accuracy

Wow! 10Hz - >2.5GHz in two ranges; 1us - 999,999s with a 12-digit LED display. It's a world beater and it's the perfect addition to any serious hobbyist's bench – or the professional engineer, technician, in fact anyone who is into electronics! You'll find it one of the handiest pieces of test gear you could ever own and you can build it yourself.

All the hard-to-get bits (PCBs, micros, LEDs, panels, etc) are available from the SILICON CHIP On-Line Shop.

You'll find the construction details at http://siliconchip.com.au/project/2.5ghz PCBs, micro etc available from On-Line Shop

university.com/learn/article/sulfation_and_how_to_prevent_it – there is discussion on the different types of battery sulphation (hard or soft) and how soft sulphation can be reversed by an over-charge to 15V or 16V (for a 12V car battery) for 24 hours. Is any of this really valid? (D. M, via email).

● This device looks like it could be a permanently fitted version of our Battery Zapper published a few years ago. It probably won't do any harm but as the discussion in your following URL shows, most of the deterioration in car batteries is caused by the fact that they are never fully charged. Short of having a 3-stage charger permanently connected to your battery whenever it is stationary, the next best thing would be to have a float charger connected when the car is garaged.

Even so, the idea that any approach, including the digital pulse generator, can increase battery life by up to three times is ridiculous. Most car batteries will typically last about four or five years without any special care, before they need replacement. And even if you do everything right and you are religious about connecting a float charger, anything over six or seven years can be regarded as exceptional.

We would also be very wary about putting a battery on a charger at 16V for 24 hours. That is likely to cause severe gassing and will substantially heat the battery and boil off a good deal of water. That will definitely cause a drastic reduction in battery life.

60Hz transformers can saturate with 50Hz mains

My friend, a local manufacturer of Aspen power amplifiers, has had problems with poor quality transformers imported from China and sold locally. The core was saturating and resultant harmonics imposed on the rails were audible. Could you write a warning

WARNING!

SILICON CHIP magazine regularly describes projects which employ a mains power supply or produce high voltage. All such projects should be considered dangerous or even lethal if not used safely.

Readers are warned that high voltage wiring should be carried out according to the instructions in the articles. When working on these projects use extreme care to ensure that you do not accidentally come into contact with mains AC voltages or high voltage DC. If you are not confident about working with projects employing mains voltages or other high voltages, you are advised not to attempt work on them. Silicon Chip Publications Pty Ltd disclaims any liability for damages should anyone be killed or injured while working on a project or circuit described in any issue of SILICON CHIP magazine.

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Soft Starter For 110VAC Power Tools

I found your article/plans/etc for the Power Tool Soft Starter (SILICON CHIP, July 2012) and I have a tool that really needs this but I am in the USA where we use 110VAC at 60Hz. My saw is rated for 110VAC at 15A (max).

Do you think I could make it work? I've tried checking with others and they said the limiting factor was 10A and that would be the limit at 110VAC as well. (P. T., via email).

● This question has been asked before and we have had reports of success. However, there is some concern since the components, including the PCB, are under about twice as much heat stress at 15A as they are at 10A (it goes by the square). However, we think there is enough safety margin built into the design for it to still be reliable.

These are the modifications you need. First, change the 330nF X2 capacitor to 680nF X2. You should be able to find one which fits the board however be careful since there may be some 680nF X2 capacitors that are larger than the space allocated.

Suitable capacitors will have a pin spacing of either 0.6-inch or 0.9-inch and will be no more than 0.4-inch wide and 1-inch long. Given the higher frequency (60Hz vs 50Hz), it's possible that a 470nF capacitor will work but it's hard to say for sure; try the higher value first, if possible.

The other issue is current-handling. Our 230VAC power outlets are generally rated at 10A giving a maximum power of 2.3kW while we believe that North American power outlets are rated at 15A, giving a power of up to 1.8kW at 120VAC. Power tools running at 120VAC will draw nearly twice as much current as those running from 230VAC for the same power rating.

The unit is designed to handle up to 10A. The specified relay is rated at 16A, the NTC thermistors at 15A and the shunt at 14A (2W) or 17A (3W) – note that the shunt was accidentally left off the parts list. It should be a 2512 SMD chip resistor, 0.01Ω, 2W or 3W. So if you use a 3W shunt, the circuit should handle 15A however we have not tested it at that current.

The biggest limitation on current handling is the current carrying capabilities of the PCB tracks. The design uses the top and bottom layers in parallel where possible so should in theory be able to handle 15A. However, they are thinner than ideal in some places for such a high current.

In short, if you change the X2 capacitor to 680nF and use a 3W shunt, it should work. You should definitely fit a fast-blow fuse rated at no more than 15A to protect the PCB tracks in case of a short on the output.

Jaycar and Altronics both have kits for this design – see www.jaycar.com.au/productView.asp?ID=KC5511 and www.siliconchip.com.au/Shop/Altronics/K6043

You will need to substitute appropriate mains power cables. The easiest way to do this is simply get an extension cord with about the right cable diameter and an earth pin and cut it in half. Obviously it needs to be rated with a high enough current to run power tools.

You can then order the two other replacement parts from a local source such as Digi-Key or Mouser. The following parts should be acceptable:

(1) Digi-Key:
www.digikey.com/product-detail/en/ECQ-UAAF684M/P14784-ND/2674016
www.digikey.com/product-detail/en/CRA2512-FZ-R010ELF/CRA2512-FZ-R010ELFTR-ND/1775029

(2) Mouser:
http://au.mouser.com/ProductDetail/Panasonic/ECQ-UAAF684M/?qs=sGAEpiMZZMv1cc3ydrPrF6ifjA0FxyZBChh3r6S1vU8%3d
http://au.mouser.com/ProductDetail/Bourns/CRA2512-FZ-R010ELF/?qs=sGAEpiMZZMtlleCFQhR%2fzcj8n28v3AVE14N6Irqfgps%3d

Substitute these two parts in the kit plus the new mains cables and it should be suitable for use at 110-120VAC.

Note that our wiring instructions are for Australian mains wiring standards which is brown for Active, blue for Neutral and green/yellow striped for Earth. Your cable will most likely be black and/or red for Active (ie, Line) white for Neutral and green for Ground. So we suggest you double-check that the wiring is correct before plugging it in.

There is one caveat: a constructor reported that the recycle time (ie, how long to wait between successive restarts to get the full soft start effect) was longer than we originally stated at 60s. We think this is due to the higher operating current causing the thermistors to heat up faster. In theory, this could be improved by adding more thermistors in a series/parallel combination but we doubt that they could be easily fitted.

article to aid in proper selection?

It is worth mentioning that only using toroidal transformers from local company Harbuch solved the problem entirely. (J. D., via email).

● Thanks for your suggestion but we have no-one on staff who is experienced in this area of transformer design.

We referred the question to Harbuch Transformers (who have been in contact with Aspen). Harbuch state that typical problems with overseas-sourced transformers relate to the fact that they are designed for a primary voltage of 220VAC or 230VAC and 60Hz rather than for Australian mains voltages which are 50Hz and which can typically range from 230-250VAC. The net result is often core saturation, poor regulation and undesirable hum.

Arduino VHF/UHF scanner wanted

Can you make a Scanner VHF/UHF Tuner Project? Old TV & VCR tuners are free and so are old AM/FM car radios. You could use them in an Arduino-controlled radio scanner.

A TV tuner takes in RF signals in the 50-861MHz range and converts them to an IF between 36MHz and 46MHz for the IF output. So can you use an old analog TV tuner as a VHF/UHF scanner? Possibly you could try programming an Arduino to control the Phase Locked Loop (PLL) if the TV tuner is a PLL type.

As a do-it-yourself home hobbyist, I do not have the radiocommunications test equipment needed to set the inter-

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Ask SILICON CHIP

. . . continued from page 102

mediate frequencies in this project and I also have no analog TV signals to test if the TV tuner is working.

Some VHF/UHF scanners cost just $100 so why bother with this? Well, the idea is that it's home-made and not all frequencies are covered by most VHF/UHF scanners; there are frequency gaps between bands. It could also be modified for radio telescope work by adding a powerful broadband RF preamplifier and dish. And it could be used for DRM/digital communications listening. I got this idea from www.uzzors2k.4hv.org (J. C., Mitchell Park, SA).

- There doesn't seem much point in using an old VHF/UHF tuner as a scanner. PAL analog transmissions have now ceased and all TV is digital.

If you want to scan all the bands, the easiest and cheapest way is to use a DVB-TV dongle with your computer, as described in our story in the April 2013 issue. This theme was further expanded in following issues with the description of a software defined radio (SDR). To see a preview of the April story, go to www.siliconchip.com.au/Issue/2013/April/How+To+Get+Digital+TV+On+Your+Laptop+Or+PC

VOX circuit required

As a member of a volunteer emergency service, we have a bank of transceivers, ie, 27MHz discrete VHF channel sets. I am enquiring if there is a kit in your vast storage of DIY kits

continued page 104

Circuit Notebook – continued from page 74

the program to define each button. As long as your measured values for the A0 voltage fall comfortably between the upper and lower limits for each button, the buttons will be successfully decoded. However, if your measurement falls uncomfortably close to one limit, you will have to alter the upper and lower limits in the program to suit.

Ideally, choose limits so that they are midway between your measured values and there must be no gaps or overlaps in the spread of the limits.

So, for example, the ideal value for the upper limit for the memory button would be (2.53 + 3.21) ÷ 2 = 2.87 and for the lower limit (2.53 + 1.85) ÷ 2 = 2.19. In the software, I have used average limits that should detect which button was pressed regardless of whether a 5.6kΩ or 3.9kΩ resistor is used.

If you need to alter the limits they are all found in the "instruction" subroutine but there is also one line in the main program loop: "if v <= 2.84 . . ." which may need changing.

When first turned on the GPS unit will initially obtain a lock on the available satellites and then the program will display the current Australian Eastern Standard Time on both displays. If another time zone is required, the program line: "Timezone = 10.0" needs to be modified appropriately.

To set the alarm times, press any of the five alarm setting keys. The alarm ON HOUR time for SUNDAY is first displayed on the LCD. Use the UP and DOWN buttons to change to the desired time. Pressing the ITEM button will change the setting shown to change successively to ON MINUTE, OFF HOUR, OFF MINUTE and finally cycle back to ON HOUR. All these values can be changed with the UP/DOWN buttons.

When satisfied that Sunday's settings are correct, press the MEMORY button and these values will be saved to memory and the day will advance to MONDAY. Proceed to set individual alarms for each day of the week and when each day has been saved to memory press EXIT to revert to normal time display mode. This will also save the alarm data to non-volatile memory so that after a power failure the alarm data is not lost and does not have to be re-entered.

One practical point to note is that you must be firm when pressing the LCD's microswitches. Because they form part of the voltage divider chain for A0, if they are tentatively pressed they may introduce some contact resistance of their own which will cause a false voltage to occur at A0 – so be firm!

If switch S1 is set to ON, then between the alarm ON and OFF times set for each day, pin 14 on the Micromite will turn on transistor Q5, which in turn activates relay RLY1 and supplies mains power the GPO. The 'ALARM ACTIVE' LED also lights as a visible indication that the GPO is powered.

Power comes from a transformer with a 9V secondary winding. A bridge rectifier provides 10-12V DC for the relay. Voltage regulators REG1 (7805, heatsink required) and REG2 (LM1117T) follow in series to supply the 5V and 3.3V rails.

Jack Holliday,
Nathan, Qld. ($85)

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that will activate a LED when voltage is applied to the speaker of a radio set. This device will allow the radio operator to identify the set that was activated, while the operator may have been distracted or temporarily out of the room.

After trawling through your archives, the nearest project that may do the job, with some major modifications, is the solar powered alarm that was printed in the March 2010 edition. I look forward to your valued opinion as to a solution. (K. B., Hawkesbury, NSW).

● A voice activated switch (VOX) is what you need. This monitors signal across the loudspeaker and switches a relay (or LED in your case). A delay is incorporated. We published a VOX in September 1994 (Jaycar kit KC5172), in July 2011 and in "Shorts Circuits 3" (Jaycar KJ8084).

For the September 1994 and "Short Circuits 3" versions, you would need a resistive attenuator to reduce the signal level to the VOX from the loudspeaker if you have a direct loudspeaker connection rather than the electret microphone. The electret bias resistor would be removed.

Photostat copies or back issues can be purchased from our website. A 1-page preview of the July 2011 article is at www.siliconchip.com.au/Issue/2011/July/Build+A+Voice-Activated+Relay+%28VOX%29 SC

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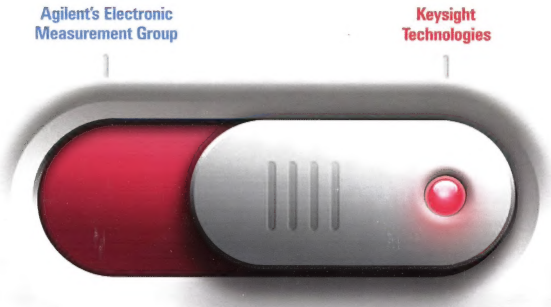

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